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REVIEW OF WORLD ENGINEERING PROGRESS
VOL. XII No. 4. APRIL, 1951

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The ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *WEAR OF RELAY CONTACTS*

In order to ensure reliable operation of the contacts of relays such as are used in communication engineering, electrical switchgear tripping devices, etc., it is necessary to make the contacts of noble metals of high melting point. Contact wear in general is preponderantly caused by the burning and the evaporation of the contact material produced by the arcing which takes place when breaking the current. It is known that there exists a lower current limit, below which no arcing will occur. If the arcing limit is not exceeded, breaking of the current will only produce a migration of contact material from the terminal constituting the anode to that forming the cathode. For the purpose of an investigation into the phenomenon of metal migration, a special type of relay has been developed which precludes bouncing of the contacts during the period of current interruption. A most interesting observation made in the course of this investigation was that a gold-nickel alloy containing 5 per cent nickel showed a migratory effect which is not only very small but at the same time goes in the opposite direction to that of the other contact metals tested. Investigations into the service life of contacts which have to operate above the arcing limit were carried out by using a circuit in which an auxiliary contact causes interruption of the arc after a predetermined length of time. For determination of the electrical characteristics of the arcing process, oscillograms were taken.

● *SOLDERS WITH LESS TIN*

The development of a group of solders has been announced which may be expected to permit savings of 50 per cent or more in the amount of tin normally used for solders. Extensive research is said to have shown that silver is the only metal readily available in sufficient quantity that can be satisfactorily substituted for part of the tin in the solder. The new tin-conserving solders are basically silver-tin-lead alloys, wherein a small percentage of silver effects a marked reduction in the tin content. There is virtually no loss in working efficiency, the new alloys giving a joint at least as good as that given by the original alloy; and finally it is claimed that the cost of the new product is less than that of the alloys replaced. The same fluxes can be used as heretofore, and the identical means of application are completely satisfactory. The new silver-bearing solders require slightly more heat to melt, but this is compensated for by the fact that too much heat is not as harmful to the new alloy as it is to the usual tin-lead solders. It is claimed that, generally speaking, the new alloys can be used for every purpose where tin-lead solders have been used. In a typical application such as the joining of sheet metal, the new alloy with 30 per cent tin content will perform as satisfactorily as the commonly used 50 per cent tin/50 per cent lead, or 40 per cent tin/60 per cent lead solder.

● *TOOTHED RUBBER BELT*

A new rubber or fabric belt with teeth is claimed to ensure positive drive and to be suitable for precision timing owing to its positive engagement with the driving and driven pulleys. This belt is similar in appearance to a flat belt except that it has regularly spaced rubber teeth along its contacting surface. These teeth engage in corresponding grooves in the pulleys. The manufacturers state that applications include high speed pumps, automatic screw machines, portable tools, electric typewriters, etc. On commercial sewing machines the belt is claimed to have made possible fifty per cent faster operating speeds. In addition to its anti-slip characteristics and precision timing, the belt is non-stretching and will operate on fixed centres without take-up adjustments. Since it needs no initial tension, it is reported to have unusually high efficiency with low bearing pressures. Speed ratios up to thirty to one are claimed to be possible and the belt can be made in any desired width and in a variety of materials, it is stated.

● *L.F. INDUCTION HEATING OF CHEMICAL PROCESS VESSELS*

Recent years have witnessed a growing interest of chemical industries in the employment of low frequency induction heating, i.e., 50 cycle operation, for the heating of chemical vessels in place of steam-jacket-heating, hitherto almost exclusively used where indirect heating was required. It need hardly be explained that induction heating offers the advantages of direct heat generation in the metal wall of the vessel and of a wide range of control of the heating effect. Considerable progress is now being made in adapting this mode of heating also to plane surfaces or only slightly curved surfaces, such as vessel-bottoms, by the

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design of disc-shaped induction heating coils. A typical feature of the new designs is the employment of a closed magnetic circuit, with an attendant screening effect. In order to take advantage of the superior heating efficiency of immersion type heaters, a special form of metal-encased, hermetically sealed, induction heating coil has also been developed which is claimed to give excellent service in distilling units. The metal case of such immersion units can be made of corrosion resisting materials, thus considerably widening the range of applications. Furthermore, by choosing immersion coil units of appropriate configuration, the coil casings may be utilized to act as guide vanes for the purpose of directing the flow of the heated liquid, thus ensuring high speed of circulation and thereby increased rates of heat transfer.

● *METER-TYPE MOTOR*

There are a number of cases in measuring technique and related fields where a miniature direct current motor of the meter-type with direct and precise linear relationship between impressed voltage and motor speed can be used to advantage. In view of the small voltages and amperages available in circuits of this type, a high degree of metering sensitivity is required. A meter-type motor recently placed on the market is reported to have wattage requirements as low as 10 microwatts, corresponding to 0·08 volt and 0·125 mA, the motor speed being 73 rpm per volt. The commutator of this motor is made of noble metal and the armature rotates in the field of a system of permanent magnets. The speed of the motor is limited by the retarding force of the eddy currents produced in the armature. This motor is claimed to be suitable for use in combination with photoelectric cells for chemographic work, etc. It can also be used for remote temperature indication and similar purposes. When used as a generator, it will generate 5·9 mV per rpm.

● *COMPOSITE TUNGSTEN CARBIDE WELD DEPOSITS*

A recent research report draws attention to certain features of hard-facing deposits which are not well known and which may affect the performance of hard overlays made from composite tube rods containing tungsten carbide granules in a mild steel tube. The sheath tubing melts during welding and dissolves both tungsten and carbon to form a hard matrix, which anchors the very hard granules in place. However, instead of being a mild steel binder for the tungsten carbide as is sometimes believed, this matrix has characteristics which range from those of tungsten steel to cast iron structure containing considerable secondary tungsten-iron carbides. It has been established that surface roughness of abraded deposits depends upon initial granule size and welding procedures. Abrasion resistance depends largely on the volume of undissolved carbides, and is generally better for gas welds. However, the hot hardness of arc welds is higher at 1200° F. The Vickers diamond pyramid micro-hardness of the primary tungsten carbide was found to be about 2400 (25-gram load), while the secondary carbide approximates to a hardness of 1750, and the other matrix constituents are softer. Arc welding may largely dissolve the primary carbides, especially if they are very fine, and thus bring about the loss of their distinctive abrasion resistance. Users of hard facings will be interested to hear that the reserach report referred to contains much useful information which is correlated with illustrations of micro-structures to serve as an aid in evaluating performance.

● *NOVEL X-RAY TECHNIQUE*

The recent development of a novel crystal amplifier which is sensitive to X-ray exposure may make it possible to introduce automatic X-ray inspection of industrial products. The new method is based upon the employment of crystals of cadmium sulphide, which is known to be a semi-conductor. When excited by X-radiation, the cadmium sulphide reacts in the same manner as a photo-conductive cell. It is stated that on an area-for-area basis, the cadmium sulphide cell is over one million times more sensitive to X-rays than are ionization chambers of the type commonly used to measure X-radiation, and over 1,000 times more sensitive than ordinary photoelectric cells responsive to visible radiation. It is reported that a prototype of the new system will shortly be delivered for a test on ordnance production problems, and pilot laboratory models have been built for a diversified range of products, including rubber heels, baby food, and blasting fuses. Although the crystals used to detect small defects, such as cavities and cracks, or the presence of foreign matter in homogeneous substances, are small, they may be grown to larger sizes, and batteries of crystals may be arranged to enable inspection of large areas to be made. In a typical test, the method was found to be capable of detecting the variation in X-radiation caused by the presence of a cavity measuring 1/16 in. diameter in a steel rod 1½ in. thick.

● *STEEL FOR HIGH PRESSURE VESSELS*

The high cost and difficult manufacture of large pressure vessels, such as high-pressure boiler drums and high-pressure vessels for the chemical and related industries, make it imperative to keep wall thickness to a minimum by using a material which retains high strength at the operating temperature in question. The latest proposal in this connection relates to the employment of a special low-alloyed steel which possesses remarkably improved strength characteristics at 350° C

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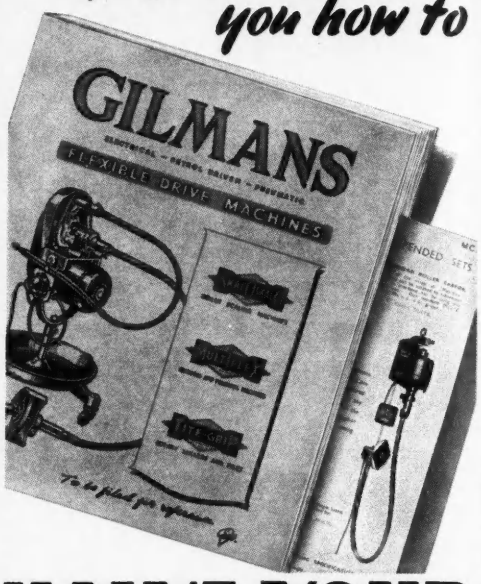

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working temperature upon having been subjected to a special heat treatment. The latter is so chosen as to produce a structure which is known as bainite, or intermediate structure. The percentage constitution of the new material is stated to lie within the following ranges: 0·1-0·2 carbon, 0·8-1·2 copper, 0·7-1·0 manganese, 0·5-0·9 nickel, 0·15-0·25 molybdenum, and tantalum-niobium contents totalling up to 0·06, while the percentages of silicon, phosphorus and sulphur may lie in the usual ranges. A typical analysis of an actual melt is given as follows: 0·16 carbon, 0·93 copper, 1·0 manganese, 0·7 nickel, 0·24 molybdenum and 0·015 tantalum-niobium. The original heat treatment adopted for this type of steel was a normalizing treatment followed by a stabilizing heat treatment at 635° C for several hours so as to prevent the precipitation of copper in service. It has now been found that the yield point at elevated temperature can be increased considerably, and a particularly favourable ratio of yield point at elevated temperature to tensile strength at room temperature can be obtained, by slowly cooling the heated material from normalizing temperature to a temperature below 200° C and then heating again to 600° C so as to effect stabilisation.

● *COMPARATIVE STRENGTHS OF ADHESIVE BONDS*

Recent years have witnessed the growing use of adhesives for industrial purposes, and, in particular, the aircraft industries have employed adhesives quite extensively. The study of the fundamentals of adhesion has, however, been relatively meagre, and it is therefore gratifying to note that a certain amount of additional information relating to the strength of the bonds between various adhesives and adherends, i.e., the materials to which the adhesives are applied, has now become available. The adhesives investigated were polyvinyl acetate, cellulose nitrate, resorcinol resin, casein, gum arabic, natural rubber, and neoprene. The adherends were stainless steel, aluminium alloy, paper-phenolic laminate, glass, birchwood, and hard rubber. The properties studied were double-lap shear, tensile, long-time loading shear, and impact strengths. The tensile-adhesion and shear strength values for a given adhesive-adherend combination did not differ greatly except for wood and paper-phenolic laminate, which are non-isotropic. The highest values—up to 3600 psi—were obtained with polyvinyl-acetate and cellulose-nitrate adhesives. The thermosetting resorcinol resin showed no appreciable flow in supporting a load of 680 psi for 6 months, whereas the thermoplastic polyvinyl acetate failed in 45 days under a load of 200 psi. The rubber-type adhesives, which were weak compared with the other adhesives in the static load tests, were definitely superior in the impact tests. Better correlation of shear strengths was observed with the moduli of elasticity than with the dielectric constants of the materials used in the various adhesive-adherend combinations.

● *EXTRUSION OF STEPPED-DIAMETER PARTS*

The technique of extruding stepped-diameter parts, such as transmission shafts, studs, and similar components, from steel bars and slugs is said to offer striking advantages in mass production. For example, once the proper slug size has been established, the work is produced without scrap loss of basic material. One manufacturer, applying the process, reports that it is possible to hold size within 0·001 to 0·002 inch on the diameters, thus reducing machining time and chip production to the very minimum. Certain parts such as steels with rolled threads and serrations can be placed in service without machining of any kind. Where parts require hardened journals, the extrusion can be made from a heat-treated bar. In such cases, cold-working further increases hardness and the part requires only selective induction hardening of the journals. In general, the extrusion operations are performed in horizontal hydraulic presses, employing cemented carbide dies for reduction in diameter. Before starting the extrusion cycle, the bars or slugs are given a special chemical surface treatment in a heated bath, which produces a strong crystalline deposit of zinc phosphate in a soap base. This takes the form of a dark shiny coating, which serves as a drawing compound of sufficient adherence to remain on the extruded part after the operation has been completed.

● *CONTROLLED WAVE-SHAPE GENERATOR*

Demands for the faster response and greater reliability of electrical control devices have stimulated investigations into the influence of the wave shape upon the performance of such devices. This is important, as a servomechanism, for instance, may function properly under sine wave conditions but may go into a state of oscillations when subjected to waves of different configuration. Electrical laboratories are not, as a rule, equipped with simple unit power sources capable of producing the wide range of wave shapes which may be required for such purposes. A surprisingly simple controlled wave-shape generator has now been developed which will deliver 100 watt output of any wave-shape voltage. The basic principle consists in the utilization of a line source of light emitted from a light slot and directed at a phototube, subsequent to modulation by an intercepting rotating cam. The wave shape desired is plotted on standard rectangular co-ordinates and then transferred to polar co-ordinate paper. From the latter a cam is cut and mounted between two transparent discs which are rotated by a motor at a

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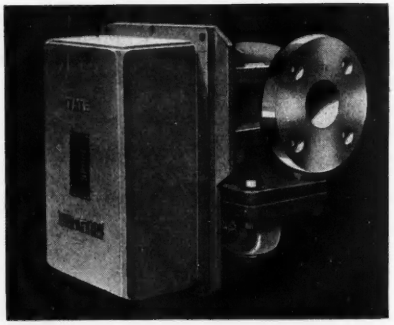

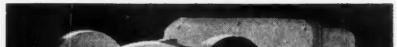

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speed corresponding to the desired frequency of output wave shape. As the periphery of the cam passes the light slot it modulates the ray, causing the phototube output to assume the wave shape plotted. The output of the phototube is then passed to an amplifier which converts the signal into usable power.

● *ULTRASONICS GENERATION BY VOLUME-MAGNETOSTRICTION*

The generation of ultrasonic vibrations is generally based upon the utilization of the variations in length of a metal rod produced by magnetostrictive effect. Magnetostriction is not, of course, limited to one dimension, but can be made to produce volumetric changes of a body placed in the alternating magnetic field. Experiments have shown that the volume change is a parabolic function of the field strength until saturation is reached, while in the saturated region a linear relationship prevails. In order to produce large magnetostrictive volume changes, comparatively high field strengths are therefore required. In a novel type of echo-sounding apparatus which has recently passed successful trials at sea, magnetostrictive volume changes are produced with the use of a disperse system of carbonyl iron powder in insulating oil. The solenoid coil producing the magnetic field is immersed in the oil and the vessel is provided with a window of metal foil or plastic, through which the selected range of ultrasonic waves is transmitted. Very large fields are produced by condenser discharge. This generator of ultrasonic vibrations has practically no natural frequency of its own, as the natural frequency of the iron particles of about 10 microns diameter is so high that it can be neglected. The condenser discharge through the field coil is produced by a spark gap, which is controlled by the ionization effect of an auxiliary spark. The use of permanently magnetic powders is being considered, as is also premagnetization to saturation by means of a direct current field.

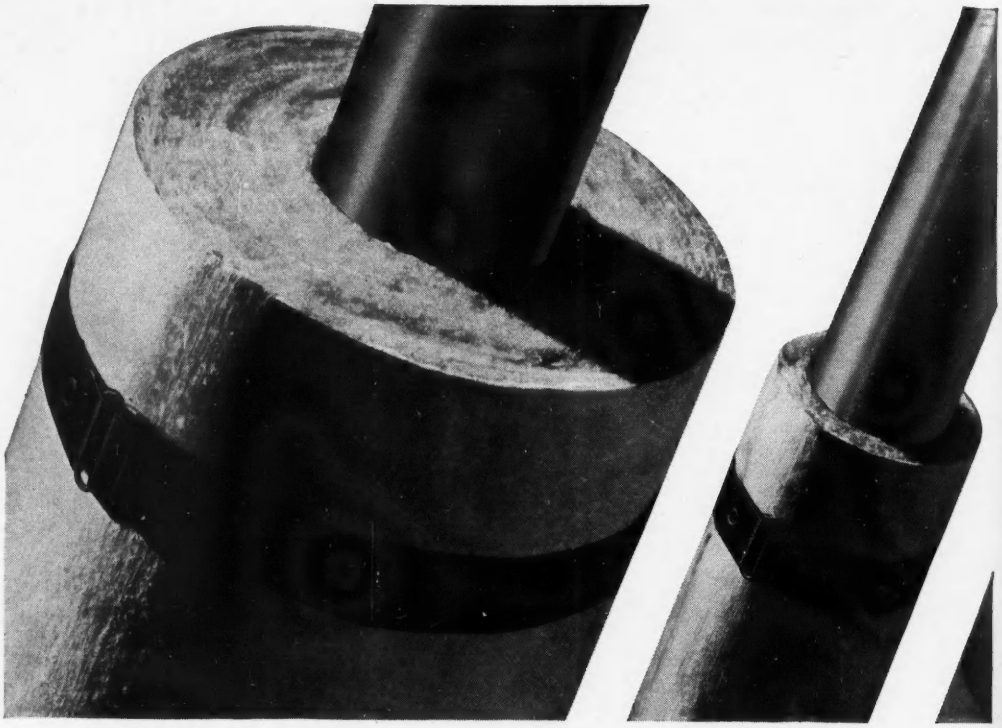
● *REFRACTORY MATERIALS FOR 2500° C*

The development has been announced of a series of sintered pure metallic oxides which have no porosity, are chemically and physically very stable even at high temperatures, and have excellent resistance against corrosion. High refractory oxide crucibles of, for instance, aluminium oxide possessing these properties can be made with comparative ease and at a reasonable cost, it is claimed. Profiled shapes and tubes, including capillaries, are also being made with such sintered microcrystalline synthetic materials. The sintering process has also been applied to oxides or oxide compounds such as beryllia, zirconia, thoria, magnesia, etc. An interesting application which is now under investigation is the use of sintered alumina in cutting tools. This application is supported by the fact that friction between two surfaces under a definite load depends not only on the smoothness of the surfaces, but also on the chemical similarity of the two materials in contact. Friction is a maximum if both materials are the same. For this reason, there is less friction when metals come into contact with oxides rather than with other metals. Also, the heated cutting surface of the sintered alumina will not form an alloy of low melting point with the metal. With regard to mechanical strength, sintered oxides are far superior to metals and to silicate ceramics; moreover, the strength of the sintered oxides remains relatively unaffected by temperatures as high as 1000° C, and even at 1200° C they still retain high strength. The oxides are fired at about 2000° C in a special gas-fired furnace based on the principle of surface combustion.

● *ANTIMONY PLATING*

It is not generally recognised that antimony has a corrosion resistance which in many respects is greater than that of any metal now commonly used for plating—excepting the precious metals. At room temperature, antimony is inert to sulphuric acid of any concentration and is attacked by nitric acid only when concentrated. The metal is inert to hydrochloric acid of any concentration in the absence of air, but is slowly attacked by the strong aerated acid. In general, antimony is resistant to all normal industrial environments wherein the oxide Sb_2O_3 is sparingly soluble. This embraces nearly all normal industrial environments except fluoride, tartrate, oxalate, citrate and highly alkaline solutions. The disadvantages of antimony are that it is as weak as lead with regard to tensile strength, yet as hard as zinc and highly brittle. These physical defects might not be so damaging if antimony were used as an electroplate on a stronger and tougher base metal. However, heretofore attempts to electroplate with antimony have generally resulted in deposits so brittle that they flake off by scratching or slight bending. It is therefore important to note that two new processes for electroplating with antimony have recently been reported. One of these processes permits the production of dull and semi-bright deposits which can be given a high lustrous finish by a light buffing operation. As antimony flows easily under the buff, it may be plated directly on a rough surface and thus polished to a high lustre in much less time than would be required to produce a corresponding finish on a steel base.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.



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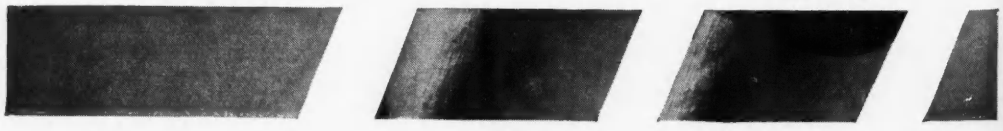

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A Swedish Pioneer Project in Power Transmission

THE island of Gotland lies in the Baltic, about 60 miles from the Swedish mainland, and, being devoid of natural power resources, must depend upon imported fuels for production of its electric power. Power transmission by submarine cable has been under consideration for some time, but investigation has indicated that it would not be economically feasible to employ alternating current for this purpose. The long transmission distance renders a d.c. cable the only possible solution to this problem.

The successful development work on the d.c. system carried out for many years by Asea, latterly in collaboration with the Swedish State Power Board, having advanced so far that the first practical application of the system appeared to be within sight, it was only natural that the Gotland power project should be the first one to be considered for a practical application of d.c. transmission.

In its initial stage, the line is intended to carry 20,000 kW, at a d.c. voltage of 100 kV, the cable current amounting to 200 A. The rectifier station on the mainland will be supplied from the 132 kV a.c. network belonging to the State Power Board. It will be combined with a station for distribution of a.c. power. The inverter station on Gotland will be connected to the 30 kV a.c. distribution network on the island. A modern steam power station will be retained for stand-by and peak power supply. Nevertheless, a synchronous condenser of 30 MVA will be installed in the inverter station, which will be able to supply the reactive power requirements of both the inverter and the network.

Only one single-pole d.c. cable will be laid, the return being effected through the water with the aid of earthing electrodes, which will be located 6-12 miles from the shore ends of the cable in order to avoid detrimental electrolytic action on the cable. Although the dielectric stresses to which the cable insulation will be subjected under d.c. are not very severe, it is evident that a submarine cable of this length presents considerable technical problems, both as regards manufacture and laying.

Two six-pulse mercury arc converters, series-connected on the d.c. side, will be installed in each shore station, each set being provided with its own transformer. The sets are made up of six single-phase ionic valves, mounted in a common frame. A seventh " by-pass " valve is provided to carry the current for brief periods in the event of transient disturbances. Each valve is equipped with its own air cooling system and vacuum pumping gear. As the valves are required to carry high and different potentials with repsect to earth, their auxiliary equipment is fed from isolating transformers, which form a characteristic feature of a high-voltage converter station.

A number of entirely new control principles and methods of protection against disturbances will be employed for the first time in the Gotland project. Frequency control of the Gotland power network will normally be effected by means of a regulator, which is sensitive to any deviation in frequency from the stipulated value, actuating the grid control of the rectifiers installed on the mainland via a radio communication link. The voltage control, on the other hand, is carried out in a more conventional manner, using a transductor regulator which controls the excitation of the synchronous condenser. Both the rectifiers and the inverters are equipped with high-speed current limitation for the purpose of suppressing disturbances due to transient faults, which are a characteristic of mercury arc converters, and restoring normal operating conditions sufficiently rapidly to obviate any danger of service interruptions.

It is also intended that the cable shall be able to transmit a certain amount of power in the reverse direction, so that the steam power station shall be able to contribute power to the mainland network in times of drought.

The Gotland project is the first of its kind, in which high voltage d.c. is used as a power link between two remote a.c. networks. It has been evident to all who have been engaged upon this project that this kind of pioneer installation entails considerable problems of a technical nature. Every effort will have to be devoted to the task of rendering this new link between the mainland and the distant island province as reliable and effective as possible.

The Smitsvonk Low-Tension Capacity Ignition

By W. Beye Smits. (From *De Ingenieur*, Vol. 63, No. 3, January 19, 1951, pp. V.1-V.9, 16 illustrations.)

This article describes the Smitsvonk low-tension ignition system and the capacitive discharge type sparking plug. Constructional details of the plug and the distributor are included, and results are also given of comparative tests of conventional high-tension plugs and the new surface-discharge type sparking element.

The theory of the ignition of fuel in spark-ignition engines is not yet fully established. It is generally assumed that a certain minimum portion of the combustible gas mixture must first be heated to a sufficiently high temperature to make the explosion self-propagating. If this condition is not fulfilled, the heat is dissipated more rapidly than it can be generated by the combustion of the adjacent layers as combustion spreads outwards. Furthermore, if the mixture is not truly gaseous, as under cold starting conditions, and contains fuel droplets, an appreciable time is required for complete evaporation. If, then, the spark is of too short a duration, or the heat energy released is too small, there may be no ignition of the mixture.

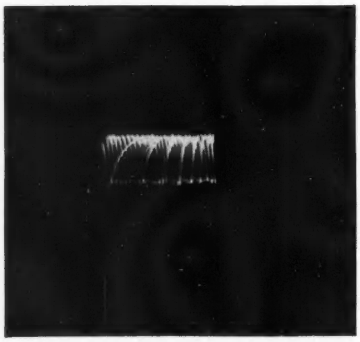

Fig. 1. **Oscillogram of a high-tension spark.**

An oscillogram of a high-tension spark is shown in Fig. 1. This oscillogram was obtained by means of the circuit of Fig. 2. The spark has an oscillatory character and is of relatively long duration. A widely adopted view is that the discharge consists of two components, (1) a capacity spark of very short duration, which is due to the discharge of energy stored in the capacitances of the plug and in parts of the ignition circuit, and (2) an inductive component or flame, which follows the capacitive discharge and is of much longer duration. This latter component consists of energy stored in the magnetic circuit, and can only be released at a slower rate.

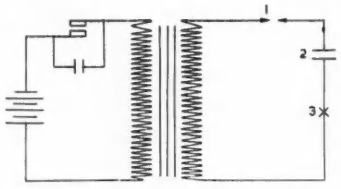

Fig. 2. **Spark discharge circuit used to obtain the oscillogram of Fig. 1.**
(1) spark gap ; (2) condenser ; (3) sparking plug.

From spark recordings obtained from engine cylinders with quartz windows, it has been estimated that the duration of the high-tension spark is of the order of 0·2 millisecond for magneto ignition, and 0·3 millisecond for coil ignition.

For a given size of gap, the tension required for the spark discharge depends on the gas pressure within the cylinder. Tests have shown that each increase of the compression ratio by one whole unit (e.g., from 7:1 to 8:1) results in a corresponding increase of about 8-10 per cent in the plug voltage.

Ignition difficulties increase also with higher engine speeds owing to the magnetic inertia of the ignition circuit. For practical purposes, it may safely be assumed that the limit as regards compression ratios is in the region of 9:1 for six and eight cylinder engines, although some alleviation is obtained by using ignition sets with double contact breakers and dual coils.

Furthermore, sparking plugs cannot be made smaller than certain minimum dimensions, so that compromise solutions have to be adopted when engine designers propose using larger valves in order to increase the volumetric efficiency.

Ignition problems occupy a prominent position in the development of automobile and aircraft engines, and it is generally realised that the limit achievable with high-tension ignition is well in sight. The present tendency is, therefore, towards the development of low-tension ignition systems. In most cases, low tension is used only in part of the system, the sparking plug still being of the high-tension type. These solutions require a high-tension transformer device in the sparking plug or just before it.

Sparking plug problems: Owing to the wide variety of engine designs, with considerably different compression ratios and engine temperatures, it is not possible to develop a universal high-tension sparking plug. Makers have, therefore, produced a range of sparking plugs having different lengths and shapes. The open-gap type of plug, with the electrodes separated by an air space, is generally preferred. The gap between the electrodes varies from 0·5-0·7 mm for normal engines, 0·7-0·8 mm for engines with relatively low compression ratios, and 0·3-0·5 mm for engines with relatively high compression ratios.

The tension required is between 8,000 and 20,000 volts. Its value is determined not only by the gap distance, but also by the material, shape and operating temperature of the electrodes. The insulator is designed so that it will attain a temperature at which the fuel and lubricant deposits will burn off, to avoid deterioration of the insulation resistance. The different coefficients of expansion of the materials used are carefully considered so as to ensure that the plug will remain gas-tight under all operating conditions.

Another type of high-tension sparking plug, viz., the " flush gap " or surface-discharge type, has also been developed. In this plug, the spark sweeps over an insulator supported under the gap of the electrodes. Although this design has various attractive features, it has not been used extensively.

Detonation and plug fouling are two further problems. The conventional sparking plugs with their high-temperature cavities considerably increase the pre-ignition tendency of fuels. The fuels, moreover, must not contain additives which, although they increase the anti-knock rating of the fuel, may bring about plug fouling. Even with gas-turbines with a constant combustion, the initial ignition is most important. In the case of jet engines, when re-lights have to be carried out under load, the high airspeed and the cleaning and cooling of the sparking plug call for special constructions.

Ignition timing: In high-tension systems fed from coils or magnetos, the timing is usually controlled by a contact breaker in the primary circuit, the opening of which induces a high-tension voltage in the secondary circuit, which is led, via the distributor to the sparking plugs. Timing accuracy depends, therefore, mainly on the time of opening of the contact breaker, which is generally of the rotating-interruptor cam type, with a movable breaker arm held down by spring pressure.

This system is satisfactory at low engine speeds. At higher speeds, however, the primary circuit does not remain closed long enough for the flux to build up to its full value around the coil in the circuit, and consequently the secondary-circuit voltage is insufficient to produce a strong spark when the primary circuit is broken. In systems in which the spark intensity varies with engine speed, delicate adjustment of the contact points is required, and frequent readjustment is necessary owing to destructive hammering and burning of the points. The tendency of the spark to jump the gap between the rotating arm and the fixed contacts of the distributor is also affected by atmospheric conditions. The gap width across which a spark can jump increases in a moist atmosphere or at reduced pressures, and this affects the accuracy of the timing.

THE SMITSVONK LOW-TENSION CAPACITY IGNITION SYSTEM

The Smitsvonk sparking plug and ignition system are based on the use of a capacitive discharge. As the initiation of combustion is a thermal process, the basic requirement is that the amount of energy available in the spark should be sufficient to ensure ignition of the mixture under all operating conditions. With a low-tension discharge, the amperage required is therefore high. A discharge path with an extremely low resistance is provided, and the discharge takes place in the shortest possible time in order to prevent dissipation of heat.

The sparking plug is of the flush gap or surface discharge type previously mentioned. This plug is particularly suitable for low-tension discharges. The resistance of the discharge path between the electrodes is less than 100,000 ohms, and each spark cleans the spark path to avoid electrical leakage. The distance between the electrodes does not exceed 0·3 mm (0·012 in.).

The spark gap is supported by a layer of semi-conductive material. In this way, a spark of very short duration (of the order of 5 microseconds) is obtained, which discharges with a very high temperature, independent of the gas pressure. The discharge has the appearance of a small flame protruding outside the spark path and penetrating into the adjacent gas layers.

The plug is designed to give good heat conductivity, so that the sparking surface will be kept as cool as possible. It has no cavities which can be filled with high-temperature combustion gases and tend to cause pre-ignition. The cool plug surfaces make it easier for fuel deposits to form on the sparking surface, which are required in order to maintain the resistance of the surface layer at a low value.

Fig. 3. **Smitsvonk low-tension capacity-discharge sparking plugs, with sparking element detached [left], and sparking element assembled [right].**

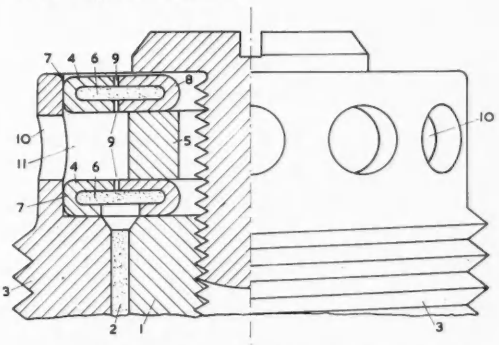

Fig. 4. (1) Spindle; (2) insulating layer; (3) shell; (4) electrode body; (5) metal ring; (6) insulation ring; (7) and (8) electrodes; (9) spark gaps; (10) holes; (11) internal space.

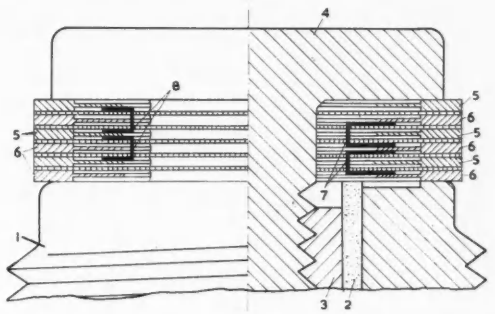

Fig. 5. (1) Shell; (2) insulating layer; (3) spindle; (4) screw connecting upper electrode (5) and lower electrode (6); (7) and (8) means for connecting electrodes of the same polarity.

Figs. 4 and 5. **Special designs providing sparking elements with long paths of wear.**

The electrodes are designed as concentric rings to give a long path of wear, as shown in Fig. 3. Further designs ensuring a long path of wear are given in Figs. 4 and 5. The spark will wander along the entire length of the spark path, always choosing its crossing point at places where the resistance is lowest. Electrode wear at a certain part of the path will immediately cause the spark to cross at another point, so that the whole length of the path is eventually worn out before the plug becomes inoperative.

The sparking element is made as a separate unit of standard size, which can easily be fitted in different sizes of plug bodies. Thus, all types of engines can be fitted with the same sparking plugs.

Oscillogram recordings of the capacity spark show that the time is so short that it can hardly be measured, which means that the energy, instead of being released in an oscillatory manner, is bundled together and released practically as a single flash, as shown in Fig. 6. The discharge is of high intensity, and the energy is so great that the effect of heat dissipation is much less pronounced. This fact has been confirmed by engine test.

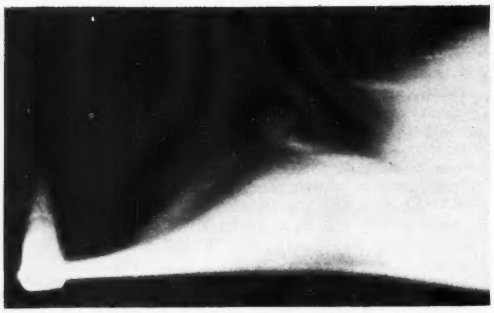

Fig. 6. **Photograph of a low-tension capacity spark, recorded through the observation window of an engine cylinder.**

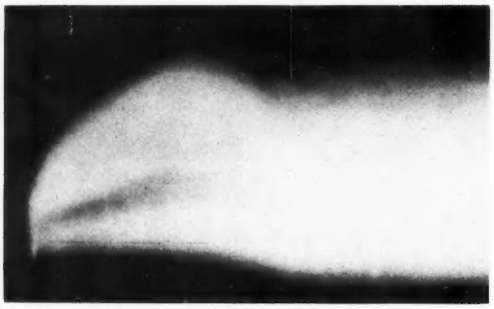

Fig. 7. **Photograph of a low-tension capacity spark, with fuel fed on to the spark path, recorded from a window engine.**

Still further improvement in combustion initiation is obtained by combining the sparking plug with an auxiliary fuel feed or a fuel injector built with it as a single unit. This construction, illustrated in Fig. 8, is useful where sparks of great intensity are required, as in industrial burners and jet engines. A special design for jet engines produces two sparks discharged from different capacities in very rapid succession. The first discharge vaporises the fuel on the sparking surface and the second ignites the already vaporised drops. An enormous flame results, with droplets of burning fuel penetrating into the combustion chamber at high velocity. Tests with jet engines have shown that even at very high combustion air speeds of 2·5 lb/sec it is possible to effect ignition with very low fuel pressures of the order of 8 psi, without any explosive effects which could damage turbine components.

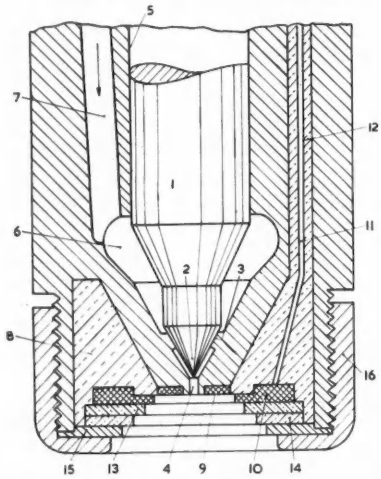

Fig. 8. **Construction in which the sparking plug and the fuel injector are combined into a single unit.**
(1) Needle valve; (2) conical point of valve; (3) valve seat; (4) fuel injection orifice; (5) passage for needle valve; (6) fuel chamber; (7) fuel feed; (8) insulating ring; (9) and (10) annular electrodes; (11) conductor; (12) insulating material; (13) insulating ring; (14) and (15) layers for compensating differential expansion effects; (16) screw cap.

Current supply: The sources of supply can be coils, magnetos or other means for charging the condenser (see Figs. 9, 10 and 11). Owing to the lower tension, insulation requirements are less severe, and a simpler construction can be used.

The coil differs from the conventional type in the proportions and disposition of the iron and copper used, since constant output is required throughout the speed range. As the coil releases its energy to a rapidly

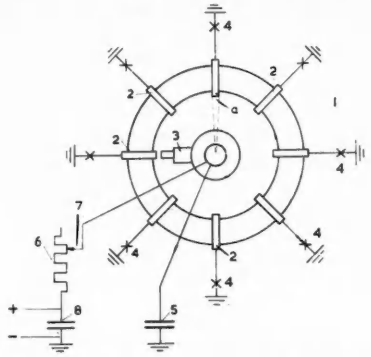

Fig. 9. **Schematic arrangement of the Smitsvonk distributor.**
(1) Distributor housing; (2) fixed contacts; (3) rotating contact arm; (4) sparking plugs; (5) ignition condenser; (6) adjustable resistance; (7) sliding contact; (8) supply condenser; (a) angle of contact between the active surfaces of the contact arm and the corresponding fixed contact.

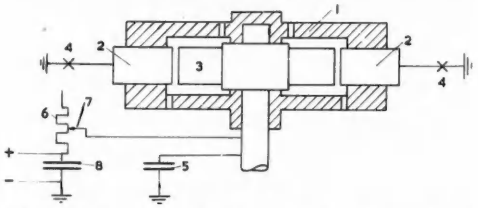

Fig. 10. **Sectional view of the Smitsvonk distributor.**
(1) Housing; (2) fixed contacts; (3) rotating contact arm; (4) sparking plugs; (5) ignition condenser; (6) adjustable resistance; (7) sliding contact; (8) supply condenser. Contacts (2) and (3) are relatively long in the axial direction, so as to give a long path of wear without affecting the accuracy of timing.

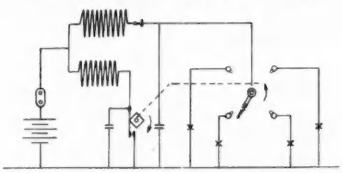

Fig. 11. **Arrangement for rebuilding a high-tension ignition system into a low-tension system.**
When the primary circuit is opened, the contact breaker causes a high tension to be induced in the secondary circuit. This is fed through a rectifier to the ignition condenser. The condenser discharge to the sparking plugs is solely controlled by the distributor.

discharged condenser and only a low tension has to be built up, the coil efficiency can easily be made very high

No contact breaker is required. The electrical energy is produced by variations of the magnetic field and the condenser is charged by suitable current blocking.

Timing: The timing system is a new design, in which the determination of the ignition spark is solely controlled by the distributor. The supply contact of the rotating arm is connected to the charged condenser, and the rotating arm touches the fixed contacts in the distributor housing, which are directly connected to the sparking plugs (see Fig. 9).

Owing to the low tension, current will only pass when a nearly direct contact is made between the rotating arm and the fixed contacts, so that timing accuracy is practically unaffected by atmospheric conditions or the condition of the dielectric. Increased accuracy is obtained by using very narrow contact surfaces, covering an arc of less than 10 degrees measured with respect to the rotating arm. Minimum wear is ensured by providing contact surfaces with considerable axial length.

Capacity ignition is particularly efficient with high-speed engines, and in this case a dual condenser system is provided. The first (storage) condenser is connected to the constant voltage supply and feeds the second condenser which is used for ignition. As there is no danger of corona discharge, pressurisation of the ignition system is no longer necessary for high-flying aircraft. The distributor can be made with very small dimensions, even for multi-cylinder engines, in view of the reduced tendency of the spark to jump gaps. Extremely smooth running is obtained, even under load, at idling speeds.

The condenser-discharge type low-tension ignition system is the first system with a universal plug suitable for all types of internal combustion engines. The plug will operate efficiently even when in an extremely fouled condition. The system is insensitive to the type of fuel used. With suitable capacitances, diesel fuels, fuels with high tetra-ethyl lead concentrations, and bituminous fuels such as tar, can be ignited.

1. *Ability to cope with high lead concentrations in the fuel:* A 55-hours' test was carried out with an experimental plug in a C.F.R. engine under the following conditions :—Engine speed 1800 rpm ; imep approx. 8 kg/cm² (113 psi) ; compression ratio 5·5:1 ; mixture strength 1·10 (10 per cent rich) ; intake temperature 70° C (158° F) ; spark advance 25 degrees ; fuel, 100/130 grade aviation petrol, with an addition of 11 cm³ of tetra-ethyl lead per Brit. Imp. gallon.

The engine was stopped abour every hour, for a check of the electrical resistance of the sparking plug. The resistance was found to vary erratically between 2,500 and 5 million ohms, and it was not possible to detect any correlation between electrical resistance and the sparking voltage. This may be explained as the result of an alternate formation and exploding of the deposits on the spark gap, so that the resistance may be altered after each spark discharge.

2. *Ability to cope with high concentrations of lead and solid-ash forming components:* Another experimental plug was tested in the C.F.R. engine under the following conditions :—Engine speed 1800 rpm ; imep approx. 8 kg/cm² (113 psi) ; compression ratio 5·5:1 ; mixture strength 1·30 (30 per cent rich) ; intake temperature 70° C (158° F) ; spark advance 25 degrees ; fuel, motor petrol, with an addition of 9 cm³ pure T.E.L. per gallon (no ethyl bromide), and 2·5 grammes (dry weight) of graphite per gallon. The graphite was added in a colloidal compound with lubricating oil.

The voltage appeared to be considerably lower than in the previous test. This was probably due to the high conductivity of the graphite and metallic lead deposits on the insulator. However, considerable variations in resistance were again apparent, and there was no correlation between voltage and resistance. The voltage at the end of the 18 hours' test was practically the same as at the beginning of the test. The compression ratio was then raised to 10 : 1 and soluble salicyl-allylamine-copper was added to the fuel, so that it would also contain 2 gr of copper per gallon. A further two hours' running showed fully satisfactory functioning of the Smitsvonk plug, although a higher voltage was necessary. During this latter test, considerable fouling of the sparking plug occurred, without affecting its efficiency. At this higher compression ratio, severe detonation was experienced, but pre-ignition still only occurred in the form of a few spasmodic bursts, presumably caused by incandescent incrustations in the combustion chamber, and it can be assumed on the basis of subsequent examinations that the plug itself did not cause pre-ignition.

The sparking efficiency was not affected by short-circuiting of the electrodes with a mixture of oil and graphite powder. The flame-like spark discharge appeared rather to have increased in size, the spark intensity being apparently sufficient to explode any foreign matter in the gap. The spark was not suppressed, furthermore, when the electrodes were submerged in water, but operated as under normal conditions.

3. *Ignition of very lean mixtures:* The C.F.R. engine was run under conditions similar to those of the previous tests, with increasingly lean mixtures, and comparative tests were made with the Smitsvonk and the conventional high-tension ignition system. It was found that whereas the leanest ignitable mixture with the conventional high-tension system corresponded to a mixture strength of approximately 0·72, a mixture strength of 0·67 could be reached with the Smitsvonk system. This means that with a given mean mixture strength of, say, 0·90, and a fuel-air ratio of about 16·5:1, for a multi-cylinder engine, the deviation from mean to lowest mixture strength can be made as high as 25 per cent. This may explain the remarkably smooth running observed at low speeds with this type of ignition.

Indicator diagrams and power and fuel-consumption measurements obtained during these comparative tests also showed that the capacity-ignition system gave slightly more favourable figures. It is considered that the improvement was due to the larger amplitude spark obtained with the capacity-ignition system, which has the result of producing greater similarity between consecutive combustion cycles.

4. *Aero-engine tests:* The ability of the capacity-type plug to ignite lean mixtures, combined with its good heat conductivity, make it particularly suitable for aero-engines. To investigate its behaviour, tests were carried out on a single-cylinder C.U.E. engine with a Wright Cyclone B.D. crankcase, with 6·125 in. bore and 6·312 in. stroke. The engine had a compression ratio of 6·5:1, an ignition advance of 25 deg., air cooling, and a carburetter fuel supply, and was run on aviation petrol of grade 100/130. The operating conditions were as follows :—(1) *cruising*, at 1850 rpm, zero boost pressure, 5·5 kg/cm² (78 psi) bmep ; (2) *take-off*, at 2200 rpm, 50 cm Hg boost pressure, 16 kg/cm² (228 psi) bmep. With the capacity type plug, the sparking plug washer temperatures were 150° and 180° C (303° and 350° F), respectively, for cases (1) and (2), whereas with the original high-tension sparking plug the corresponding temperature was 215° C (420° F) for both cases.

5. *High-altitude operation:* For this investigation a special apparatus was developed, in which two sparking plugs could be tested simultaneously. The apparatus consisted of four chambers, with two on the front and two on the rear side of the casing. The sparking sides of the plugs protruded into the two front chambers, which were maintained at a constant pressure of

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U.S.A.

Engineering Applications of Silicones

By I. W. HUTCHISON. (From *The Tool Engineer*, Vol. 26, No. 3, March, 1951, pp. 38-40, 4 illustrations.)

As silicones are a chemical combination of both inorganic and organic materials, they possess some of the properties characteristic of both classes of materials. For example, silicones are resistant to temperature extremes, to chemicals and to moisture. They possess good dielectric properties and may be produced in several different physical forms.

THERE are now about 80 different silicones commercially available in the U.S.A. For ease of discussion these may be divided into these four groups: (1) Fluids and oils; (2) Compounds and greases; (3) Resins and varnishes; and (4) Elastomeric materials (silicone rubber).

APPLICATIONS OF FLUIDS OR OILS

The first large-volume peacetime use for silicones was in the rubber industry as mould release agents or die lubricants. The best mould lubricant is that one which gives immediate release even though only a thin film is used. This is especially important in the tyre industry, tyre moulds being sprayed with a silicone release agent. Silicone release agents are also used as lubricants for die casting zinc and aluminium.

In addition to their release property silicone fluids also possess the ability to maintain a relatively constant viscosity over a wide range of temperatures. This makes them suitable as hydraulic oils and damping media.

BEARING LUBRICANTS

Silicone fluids or oils are also used as bearing lubricants. In the case of one oil furnace fan motor, the bearings of this well engineered unit are oil-lubricated and customers were advised to change oil only once a year. The customer did not do so, with the result that in two or three years the oil was badly oxidized and carbonized and the entire unit had to be replaced. The company's engineers had been searching for a solution to the problem, but it was not until they tested a silicone fluid that they found the answer. Accelerated breakdown tests indicated that one application of silicone fluid would provide adequate lubrication for at least four to five years. Lifetime field tests confirmed these results.

Silicone fluids are also used to prevent foaming in petroleum oils. This is a serious problem with both straight cutting oils and with the soluble oils frequently used to lubricate and cool high-speed drills, and other cutting tools. Most remarkable about this application is the concentration required; only one part of silicone fluid per million parts of oil is sufficient.

APPLICATIONS OF COMPOUNDS AND GREASES

Chief among the applications for the silicone compounds are those resulting from the release properties characteristic of these semi-solid materials. These inert compounds are used wherever a release agent is required in the rubber, plastics and plywood industries. Applied from a solvent dispersion, one silicone compound is a most effective agent in the Croning or "shell" process for casting non-ferrous parts. Other silicone compounds are used as waterproof dielectric seals for ignition systems, electrical control circuits, and radio and radar equipment.

Good lubricity combined with stability at high temperatures and excellent oxidation resistance are the reasons why silicone greases are considered essential in a wide variety of industrial applications. These inert greases are used to lubricate ball bearings operating at high and low temperatures and such low-speed, high-temperature equipment as conveyor bearings, oven machinery and pumps handling hot liquids.

APPLICATIONS OF RESINS AND VARNISHES

This group of silicones, more than any other, has led to the commercial development of silicones in the United States.

Disregarding the metal portion, there are only two constituents which determine how hot a motor can be run. Before glass cloth became available, the spacing materials (formerly paper or cotton) and the binders had about the same order of heat resistance. But with the development of glass fabrics, the resin and varnish binders became the inherent limitation.

It was obvious that if the additional heat and moisture resistance of the glass materials was to be fully utilized, binders of equivalent heat stability were necessary. The silicone resins and varnishes ultimately developed possess the heat stability necessary for full utilization of glass electrical insulating components.

High temperatures in motors can be caused either by overloads or by ambient conditions. One such problem involved motors driving coilers which take red-hot steel strip from an 80-inch mill and roll it into coils. At the same time the strip is cooled with water. Thus these motors are exposed to water, steam, high ambient temperatures, and overloads. The average life of motors wound with Class B insulation was two months. Silicone-insulated motors are still in service after 14 months.

In addition to increased service life there are other advantages to be gained by a more heat-stable electrical insulation such as silicone insulation. Design engineers may now build smaller and more compact motors. The motors may heat up without injury to the silicone insulation because it easily withstands operating temperatures of 200 to 250° C. Smaller units mean savings in weight and space which are often very important considerations. Comparing a standard Class A motor and a silicon-insulated motor, both rated at 5 hp, the latter weighs only 60 per cent as much as the standard motor, and occupies much less space.

Other silicone resins are used as vehicles for high-temperature paints and enamels. Paint deteriorates rapidly on hot surfaces such as chimneys, mufflers, and exhaust cylinders. Also, white enamels do not stay white long; they slowly yellow with age. Silicone resins, with their inherent stability to heat and oxidation. have solved many such troublesome problems. These resins require baking to develop their properties, hence silicone paints are not yet available for exteriors of dwellings, but should become available in the future.

APPLICATIONS OF SILICONE RUBBER

The fourth group is silicone rubber, which is able to withstand temperatures of 500° F and yet remain flexible at temperatures of minus 100° F.

The material is available in two forms, one a thick heavy paste, the other a stock or "crepe." The pastes are used to coat glass cloth and as caulking and potting compounds. The stocks or "crepes" can be moulded, extruded, laminated, calendered or sheeted to form gaskets, seals, diaphragms, hose and mechanical parts.

Industry has many applications which require gaskets and seals to remain flexible at high temperature. Quite often it is necessary to make elaborate design changes to put the gasket location away from the source of heat. Silicone rubber provides a flexible gasket which makes possible simpler and less expensive designs.

An Investigation on Boron-Treated Medium-Carbon Steels

By Y. IMAI and H. IMAI. (From *The Science Reports of the Research Institutes, Tohoku University*, Vol. 2, No. 2, 1950, Series A, pp. 260-269, 11 illustrations.)

Small additions of up to 0·003 per cent boron increase the hardenability of steels and may be used to replace more expensive alloying elements. The American Iron and Steel Institute thus suggests the use of certain standard boron-treated steels as substitutes for restricted alloy steels. The paper shows that the hardenability is a maximum for 0·003 per cent boron and decreases with higher boron content. The effect is due to increased nitride precipitation during quenching and tempering, but is markedly reduced if the nitrogen content of the steel exceeds 0·008 per cent. De-oxidation and de-nitrogenization by additions of aluminium or titanium prior to boron-treatment further improve the hardenability.

THE solubility of boron in γ-iron is 0·15 per cent, in α-iron 0·10 per cent, so that the effect of only 0·003 per cent boron cannot be explained by direct super-saturation. It is believed that nitrogen dissolved in steel plays an important rôle for the boron treatment and that the nitride precipitations during cooling are very finely dispersed by the boron additions. In the following tests, the steel was de-oxidized by silicon additions (0·1 to 0·2 per cent) before ferro-boron (0·3 C ; 2·3 Si ; 11·2 Al ; 10·2 B, approx.) was added in the very small amounts required.

1. EFFECT OF BORON ADDITIONS ON NITRIDE PRECIPITATION

It is known that during tempering of hardened steels, nitride is precipitated prior to, and at lower temperatures than, carbide[1]. If test specimens of 0·3 per cent C steels with and without 0·008 per cent boron are heated for 30 minutes at 950° C, then quenched in water and tempered for various lengths of time at different, constant, temperatures from 50 to 250° C, the boron-treated steels attain their maximum Vickers hardness after appreciably shorter tempering times than the plain steels treated at the same temperature. Nitride precipitation is thus more pronounced in boron-treated steels than in plain steels. The change of magnetic coercive force during tempering illustrates this effect in greater detail (Fig. 1) : The nitride

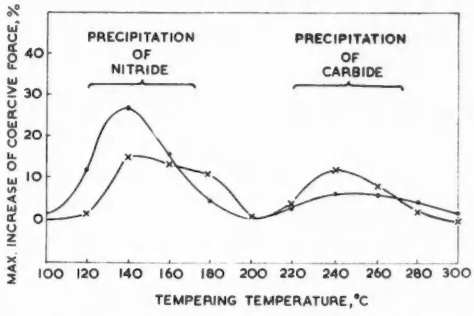

Fig. 1. **Change of magnetic coercive force on tempering.**
• ——— • 0·2% C, 1·8% Mn, 0·008% B.
× ——— × 0·2% C, 1·8% Mn.

precipitation occurs at lower tempering temperatures and is increased by boron addition, whilst the carbide precipitation is slightly reduced by such addition. Similarly, isothermal transformation below 400° C of 0·3 per cent C steels with and without 0·05 per cent boron shows, by microscopic examination after etching with a modified Fry's reagent, that the boron-treatment accelerates the start of nitride precipitation and retards that of carbide precipitation. Boron-treatment may therefore be said to promote nitride precipitation near the Ar_1-point ; the precipitates then constitute nuclei for the formation of martensite whilst, at the same time, increasing the stability of the super-saturated carbon structure, so that the hardenability of the steel is improved.

TABLE I.—BORON-TREATED STEELS WITH VARIOUS BORON CONTENTS.

Specimen	C%	Si%	Al%	B%
C	0·31	0·13	0·027	0·0027
D	0·29	0·12	0·069	0·005
E	0·30	0·15	0·13	0·016
F	0·21	0·13	<0·01	0·008
G	0·26	0·13	<0·01	0·028
H	0·29	0·13	0·01	0·041
I	0·30	0·15	—	—

Nitrogen content 0·004-0·006 per cent.

2. BORON CONTENT FOR MAXIMUM HARDENABILITY

Test bars of 5 mm diameter and 100 mm length (0·2 in. diameter, 4 in. length) of various steels (Table I) were heated for 10 min. at 900° C. One end of the test bar was then quenched in water of about 12 mm (½ in.) depth. A longitudinal section was etched and the distance from the fully quenched portion to a point showing half-martensitic, half-troostitic structure was measured. This " hardened length " may be taken as a criterion of the hardenability and plotted against the boron content of the test bar (Fig. 2). The maximum hardenability thus defined is obtained for a steel containing about 0·0027 per cent boron, and the hardenability decreases, first rapidly then slowly, with further increasing boron content. This may be explained as follows : A small amount of Fe_2B-precipitation can be detected at the grain boundaries even when only 0·0027 per cent boron is present, and the amount of Fe_2B-precipitation increases quickly with increasing boron content. This amount of Fe_2B does not change during hardening, i.e., the compound does not dissolve in austenite and acts as a nucleus accelerating the transformation towards pearlite. The optimum amount of effective boron dissolving in austenite at the hardening temperature and thus contributing to hardenability must, therefore, be lower than 0·0027 per cent. However, some added boron, depending on the nitrogen content of the steel, is fixed as nitride and does not dissolve in austenite ; another part is lost as oxide and thus does not affect the hardenability, so that the optimum amount to be added is difficult to determine. It can therefore only be stated that maximum hardenability is obtained with about 0·003 per cent boron in steels containing 0·004 to 0·006 per cent nitrogen, provided

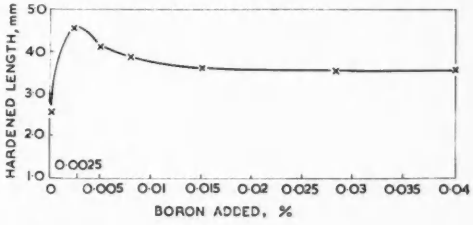

Fig. 2. **" Hardened length " i.e., distance from fully quenched portion to a point showing half-martensite half-troostite in a longitudinal section, as a function of the boron content in 0·3 per cent C steel bars quenched at one end. The " hardened length " is a measure of the hardenability.**

the steels are well de-oxidized before addition of the boron. This result coincides with many experimental figures obtained by American investigators.

3. Effect of nitrogen content in boron-treated steels

Research in the U.S.A. has shown that the increased hardenability due to boron additions is most marked in basic open-hearth steels and less pronounced in steels made in electric-arc or high-frequency furnaces ; the former contain 0·001 to 0·008, the latter 0·006 to 0·040 per cent N_2. It is also known that a high nitrogen content seriously impairs the effect of boron-treatment.[2] The writers have confirmed and amplified these results by quenching tests, conducted as previously described, with steels of increased nitrogen content (Table II) ; manganese nitride containing 7·4 per cent N_2 was added prior to boron-treatment. Fig. 3 shows the hardness distribution along the quenched test bars and Fig. 4 the "hardened length" as defined in connection with Fig. 2. The hardenability of the steel decreases slowly as the nitrogen content is increased from 0·004 to 0·008 per cent, but then drops rapidly, and the effect of the boron-treatment is nil when 0·02 per cent N_2 is present with 0·004 per cent B. This change is only partly due to the grain refinement caused by a high N_2 percentage ; the main reason is the strong affinity of boron for nitrogen. Part of the added boron is fixed as nitride, which hardly dissolves in austenite even at high temperatures. The quantity of effective boron soluble in austenite decreases markedly with increasing nitrogen percentage, and with 0·02 per cent or more N_2, almost all the added boron is fixed as nitride and is ineffective. Tempering tests with the same steels (Table II) also show the influence of nitrogen. The quenched

Table II.—Boron-treated steels with various nitrogen contents.

Steel No.	C%	Si%	Mn%	B%	N_2%
1	0·34	0·12	0·28	0·004	0·004
2	0·34	0·06	0·30	0·004	0·008
3	0·33	0·06	0·29	0·004	0·011
4	0·31	0·08	0·29	0·003	0·019
5	0·31	0·07	0·30	0·004	0·022
6	0·33	0·07	0·31	0·002	0·028
27	0·34	0·12	0·28	—	0·005

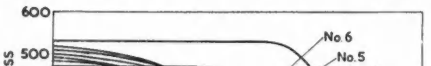

Fig. 3. **Hardness distribution along partially quenched test bars of boron-treated steels with high nitrogen content. Water quench after 10 min. at 900° C.**

Fig. 4. **Effect of nitrogen content on the hardenability of 0·3 per cent C, 0·003 per cent B steels.**

Table III.—Steels with and without boron and with various aluminium additions.

Steel No.	C%	Si%	Mn%	B%	Al%	N_2%
7	0·26	0·08	0·24	0·002	0·03	0·004
8	0·32	0·09	0·26	0·003	0·11	—0·006
9	0·29	0·17	0·28	0·004	0·26	
13	0·35	0·08	0·28	—	0·009	0·007
15	0·34	0·08	0·26	—	0·04	0·008
16	0·29	0·10	0·24	—	0·13	0·006
17	0·35	0·12	0·28	—	0·25	0·005
1	0·34	0·12	0·28	0·004	—	0·004
27	0·34	0·12	0·28	—	—	0·005

Table IV.—Steels with and without boron and with various titanium additions.

Steel No.	C%	Si%	Mn%	B%	Ti%	N_2%
10	0·33	0·12	0·25	0·005	0·04	0·004
11	0·34	0·17	0·26	0·003	0·15	—0·006
12	0·29	0·17	0·24	0·002	0·27	
18	0·35	0·10	0·26	—	0·03	0·006
19	0·33	0·12	0·27	—	0·13	0·004
20	0·32	0·11	0·25	—	0·24	0·007
1	0·34	0·12	0·28	0·004	—	0·004
27	0·34	0·12	0·28	—	—	0·005

specimens were tempered at 150° and 200° C, and the time required to reach maximum hardness was found to increase with increasing N_2 content of the boron-treated steel. The increase became noticeable at 0·01 per cent N_2, and the tempering time was equal to that of a plain steel without boron when N_2 exceeded 0·02 per cent (200° C) or 0·027 per cent (150° C). It is therefore desirable to reduce the nitrogen content in steels before boron is added.

4. Effect of aluminium or titanium in boron-treated steels

Additions of aluminium as well as titanium de-oxidize and de-nitrogenize steels and, if added prior to boron-treatment, should therefore improve the boron effect. The previous quench tests were thus extended to the steels of Tables III and IV, and the resulting "hardened length," as defined in connection with Fig. 2, plotted as a function of the Al or Ti content (Figs. 5 and 6). The steels of Table III were de-oxidized with Si before Al was added, so that the loss of Al as oxide was minimised.

Fig. 5. **Effect of aluminium additions on the hardenability of plain and boron-treated 0·3 per cent C steels.**

Additions of 0·03 per cent Al very slightly decrease the hardenability of boron-treated steels (Fig. 5) : the marked grain refinement masks the desirable de-nitrogenizing action of Al. The hardenability is definitely improved if 0·1 per cent or more Al is added since the free nitrogen capable of fixing boron as nitride is then reduced to a minimum. Moreover, the strong de-oxidizing action of Al also improves the boron-hardenability, but this effect could only be small as the steel was first de-oxidized with Si. The hardenability of 0·3 per cent C steels without boron is also improved by addition of 0·1 per cent or more Al (Fig. 5). Titanium is more effective than aluminium (Fig. 6). Even additions of only 0·03 per cent Ti appreciably improve hardenability, because (a) the grain refinement due to

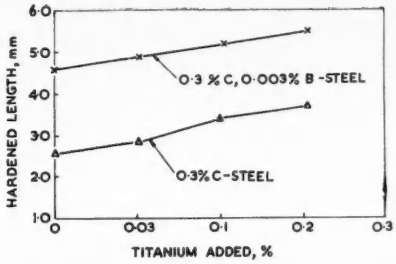

Fig. 6. **Effect of titanium additions on the hardenability of plain and boron-treated 0·3 per cent C steels.**

Ti is less pronounced than that due to Al, and (b) Ti has a greater affinity for nitrogen than Al. The de-oxidizing effect of Ti probably also slightly improves the hardenability of boron-treated steels.

CONCLUSIONS

(1) Nitride precipitation precedes carbide precipitation on tempering of hardened steels at low temperatures of 150 to 200° C, and is markedly promoted by small additions of boron.

(2) The hardenability of boron-treated medium-carbon steels is at a maximum with additions of 0·003 per cent B, decreases sharply with further additions, and is finally constant when the boron content exceeds about 0·015 per cent.

(3) Free nitrogen in steels fixes boron as nitride and reduces the effective boron soluble in austenite. The hardenability of boron-treated steels thus decreases markedly when the nitrogen content exceeds 0·008 per cent, and the effect of boron is completely suppressed by 0·02 per cent N_2. Nitrogen up to 0·008 per cent does not affect the hardenability.

(4) Additions of 0·1 per cent aluminium or 0·03 per cent titanium prior to boron-treatment strongly de-oxidize and de-nitrogenize the steel, and thus improve its hardenability.

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SWEDEN

The Efficiency of Heat Engines

By W. TRAUPEL. (From *Teknisk Tidskrift*, Vol. 80, No. 46, December 16, 1950, pp. 1157-1164, 10 illustrations.)

This article describes a new method for the practical calculation of the thermal efficiency of heat machines operating with one or several working media. The evaluation of the entropy of reversible and irreversible processes is treated in detail. The working cycles of six different types of heat machines are analysed and compared, and the results are used to assess the possibilities of improvement of the different cycles.

THE cycle of a heat machine operating with one or several working substances can be represented in the general case by an entropy-temperature diagram such as that shown in Fig. 1. The cycle may include several branches, that is, a portion of the working medium may be separated from the remainder and may follow a process differing from the original. As the quantity of working medium per unit time is different for different branches, the area of the diagram has no direct significance. If the medium in a process undergoes chemical changes, the curve will not be fully closed. In Fig. 1, it can be seen that the curves AC and BD break off, and have a continuation proceeding from point E. This represents the effect of the combination of two chemically different gases at a constant temperature, which is always associated with an increase in entropy. If the gases have different temperatures, there is a further increase in entropy due to temperature compensation.

To obtain a better energy utilisation, the process is in many cases subdivided intentionally into several branches, for example, when feedwater heating with bled steam from the main system. In other cases the subdivision is not intentional : for instance, when steam or air flows through a labyrinth gland, a sort of lateral branch is created. In piston engines, the working substances also go through various transformations occurring in branch processes, as, for instance, in two-stage expansion.

The above considerations can be used to develop a theory, valid for all types of heat machines, enabling assessment of the losses and taking account of the secondary processes.

The quantity of heat dq which is supplied along a boundary line element dl to the working medium, per unit weight, is generally given by

$$dq = dq' - dq'' + dq_v + dq_i \quad .. \quad (1)$$

where dq' = heat supplied from external heat source or by chemical reaction, dq'' = heat given up to external surroundings, dq_v = heat developed by irreversible changes from work converted into heat during the same process, and dq_i = internal heat, i.e., heat received from other parts of the process. Eq. (1) may also be expressed as a change in entropy by writing

$$ds' = dq'/T, \; ds'' = dq''/T, \; ds_v = dq_v/T, \; ds_i = dq_i/T.$$

Whereas dq', dq'' and dq_v are always positive, dq_i can be either positive or negative. Internal heat utilisation is either intentional (as when heat exchangers are used with gas turbines) or unintentional (as, for instance, in steam engine cylinders, in which part of the steam condenses on the walls and later evaporates again suddenly, with detrimental effects).

The total quantity of heat supplied to the process from outside sources or by chemical reactions is

$$Q' = \Sigma \left\{ \int G dq' \right\} \quad .. \quad .. \quad (2)$$

G being the weight of the working medium. The integral for each branch process is determined first and the results are then added together. The value of G along one branch may be either constant or variable. The total change in entropy, due to the heat supplied Q', is

$$\Delta S' = \Sigma \int (G dq'/T) \quad .. \quad (3)$$

In general, its value cannot be determined from an ordinary T-S diagram, because dq is not necessarily equal to the value of Tds indicated in the diagram.

The mean temperature of the heat supplied will now be defined as the temperature T' which, when multiplied by $\Delta S'$, gives Q', that is

$$T' = Q'/\Delta S' \quad .. \quad .. \quad (4)$$

Similarly, in considering the heat transmitted to the external surroundings, we have

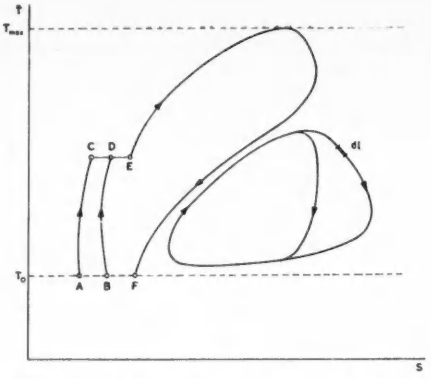

Fig. 1. **Entropy diagram for a cycle comprising branch processes with different working media.**

$$Q'' = \Sigma\Big\{ \int G dq'' \Big\} \quad .. \quad (5)$$

$$\Delta S'' = \Sigma \int (G dq''/T) \quad .. \quad (6)$$

and $$T'' = Q''/\Delta S'' \quad .. \quad .. \quad (7)$$

The thermal efficiency is, therefore,

$$\eta_t = [Q' - Q'']/Q' = 1 - (Q''/Q') = 1 - (\Delta S''/\Delta S') \times (T''/T') \quad .. \quad (8)$$

The ratio $\Delta S''/\Delta S'$ will now be considered. From eqs. (1) and (6) we have

$$S'' = \Sigma \int (G dq'/T) + \Sigma \int (G dq_v/T) + \Sigma \int (G dq_i/T) - \Sigma \int (G dq/T) \quad .. \quad .. \quad (9)$$

For a closed cycle without chemical changes, the last term of the right-hand side of this equation is equivalent to $\Sigma \int G ds$ and hence equal to zero in this case. However, as soon as a chemical change takes place, the ds-value related to the curve element dl is not equal to dq/T. According to the third law of thermodynamics, the entropy of a substance is fully determined by its thermodynamic and chemical state, and does not require the further determination of the value of an arbitrary constant. Therefore, the change in entropy which is associated with a reaction, determined in this way, is not necessarily identical with dq/T.

The relation $ds = dq/T$ is valid only for reversible changes of state. The equation can only be extended to an irreversible change if this can be replaced by an equivalent reversible process without losses. For example, in the case of work irreversibly converted into heat, a reversible process is considered in which a quantity of heat is supplied from the outside, which is exactly equal to the heat generated by internal friction. Then we may write $ds_v = dq_v/T$. Moreover, if isothermal combinations of chemically different gases occur, then $ds > 0$ although $dq = 0$. These examples show that one cannot, without further consideration, read the value of $\Sigma \int G dq/T$ directly from the T-S diagram of Fig. 1.

However, one can give these terms a more direct meaning by using a "modified entropy diagram" obtained as follows :—Each line element dl in the original entropy diagram is replaced by an element dl^*, the end points of which are on the same isothermals as dl, but with a corresponding value ds^* which is taken as being equal to dq/T. All these dl^* are plotted consecutively so as to obtain a continuous line. (For isothermal combinations, $dq = 0$; non-isothermal combinations are replaced by isothermal combinations plus the heat developed). Fig. 2 shows the modified entropy diagram, in accordance with the above. Then, using the notation of Fig. 2, we have

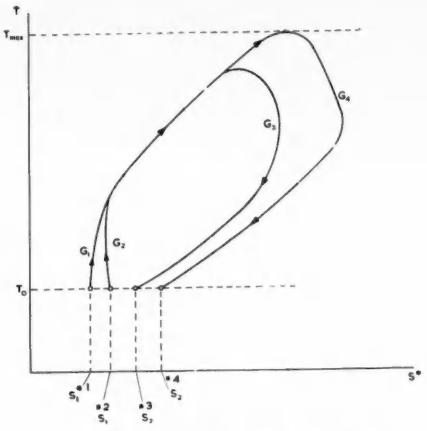

Fig. 2. **Modified entropy diagram.**

$$\Sigma \int (G dq/T) \quad \Sigma \int G ds^* = G_3 S_2^{*3} + G_4 S_2^{*4} - (G_1 S_1^{*1} + G_2 S_1^{*2}) \quad (10)$$

or, more generally,

$$\Sigma \int (G dq/T) = \Sigma G S_2^* - \Sigma G S_1^* = \Delta S^* \quad (11)$$

where all starting points are denoted by the subscript 1 and all end points by 2. The sums are taken for the starting and end points of all the branches.

The meaning of ΔS^* becomes clear if we divide it by ΣG (the total weight of the working medium), to obtain $\Delta S^* = \Delta S^*/\Sigma G$. This is equal to the mean value of the gap between the various starting points and end points at the temperature T_0 in the modified entropy diagram. This diagram is thus a practical entropy diagram which can be rapidly constructed by engineers when dealing with processes including irreversible chemical reactions and isothermal diffusion.

Using the notation

$$\Delta S' = \Sigma \int (G dq'/T), \quad \Delta S_{v,i} = \Sigma \int G dq_{v,i}/T),$$

$$\sigma_v \quad \Delta S'/\Delta S_v \text{ and } \sigma_i \quad \Delta S_i/\Delta S',$$

the entropy ratio $\Delta S''/\Delta S'$ can be rewritten as follows :—

$$\Delta S''/\Delta S' = 1 + \sigma_v + \sigma_i - \sigma^* \quad .. \quad (12)$$

where $$\sigma^* = \Delta S^*/\Delta S' = [\Sigma G S_2^* - \Sigma G S_1^*]/\Sigma \int (G dq'/T) \quad (13)$$

and the thermal efficiency is then given by

$$\eta_t = 1 - (1 + \sigma_v + \sigma_i - \sigma^*)\, T''/T' \quad (14)$$

This equation is valid for all types of heat machines, and determines the thermal efficiency as a function of five quantities, viz., the mean temperatures T'' and T', and the coefficients σ_v, σ_i and σ^* representing the frictional and flow losses, the internal heat losses, and the effect of chemical changes.

In order to characterise a process it is convenient to replace by non-dimensional quantities the mean temperatures T' and T'' of the heat supplied and the heat transmitted to the external surroundings. If T_{max} = maximum temperature, and T_0 = ambient temperature, we can write

$$\tau' = T'/T_{\max} \ (\tau' < 1) \quad .. \quad (15)$$

$$\tau'' = T''/T_0 \ (\tau'' \geq 1) \quad .. \quad (16)$$

Moreover, $\sigma_v = 0$ and $\sigma_i = 0$, but no statement can be made regarding the sign of σ^*, since ΔS^* can be either positive or negative. We consider the case that, for a certain fuel, ΔS^* and hence σ^* is positive, and apply this to an ideal heat machine, for which $\sigma_v = \sigma_i = 0$ and $\tau' = \tau'' = 1$. Then

$$\eta_t = 1 - (1 - \sigma^*)\,(T_0/T_{\max}) \quad .. \quad (17)$$

which is greater than the Carnot efficiency

$$\eta_C = 1 - (T_0/T_{\max}) \quad .. \quad .. \quad (18)$$

The possibility of exceeding, in principle, the Carnot efficiency was already pointed out by Stodola. Unfortunately, it is found that none of the known fuels gives for σ^* a sufficiently positive value. Instead, most fuels give a negative value, so that the Carnot efficiency is never reached. However, an infinitely great number of ideal processes can be found which reach the Carnot efficiency if we put $\sigma^* = 0$. They produce the same amount of work if $\tau'' = \tau' = 1$, since $\sigma_v = \sigma_i = 0$ is always fulfilled for an ideal process, so that $\eta_t = \eta_C$.

Cases occur in which it is not clear which temperature should be taken as the ambient temperature T_0. For instance, when dealing with gas turbines with intercooling, in which air is aspirated from the outside and a portion of the heat is carried away by cooling water, it is a question whether the temperature of the outside air or that of the cooling water should be regarded as T_0. It is therefore suggested that, in all cases, the lowest temperature be designated T_0, since it is always possible to cool the warmer medium with the colder medium.

(To be continued)

RUSSIA

The Design of Bearings for Piston Engines

APPLICATION OF THE THEORY OF EFFECTIVE LOADS

By A. K. DYACHKOFF. (From *Izvestiya Akademi Nauk, S.S.S.R.*, No. 11, November, 1950, pp. 1615-1644, 8 illustrations.)

I. THE BASIS OF THE THEORY

THE hydrodynamic theory of lubrication is the basis for the design of plain bearings for modern engines. In principle, the minimum oil film thickness is determined which is likely to occur under the most unfavourable conditions of manufacture, assembly and operation. An important factor is the temperature of the oil film and of the bearing material at the point of minimum clearance. Whilst the general tendency will be towards a low temperature, this should not be too low, as a very high viscosity may, under certain conditions, prevent the oil flow and with it the cooling effect of the oil, so that an overheated bearing may be the result.

Elsewhere,* the author has developed the following general expression for the pressure in an ideal cylindrical bearing of infinite width, with complicated loading conditions :

$$p = 6\,Z\left(\frac{d}{\eta}\right)^2 \epsilon^2 \left[(\omega - 2\,\Omega)\int_{\theta_1}^{\theta} \frac{\cos\theta_m - \cos\theta}{(\epsilon + \cos\theta)^3}\,d\theta + \frac{4\,\epsilon\,V_s}{\eta}\int_{\theta_1}^{\theta} \frac{\sin\theta_m - \sin\theta}{(\epsilon + \cos\theta)^3}\,d\theta\right] \quad .. \quad (1)$$

where

- p = local pressure inside the oil film,
- V_s = velocity of translation of centre of rotating element along line connecting centres of shaft and bearing,
- Z = absolute viscocity of lubricating oil in loaded portion of film,
- d = journal diameter,
- η = diametral clearance of bearing,
- ϵ = coefficient of eccentricity, the reciprocal of eccentricity of journal in bearing clearance,
- ω = angular velocity of journal,
- Ω = angular velocity of line connecting centres of journal and bearing,
- θ_1 = angle between line connecting centres and radius vector through initial point of pressure generation within oil film,
- θ_m = angle between line connecting centres and point of maximum pressure in oil film,
- θ = angle between centre-connecting line and any given point of oil film.

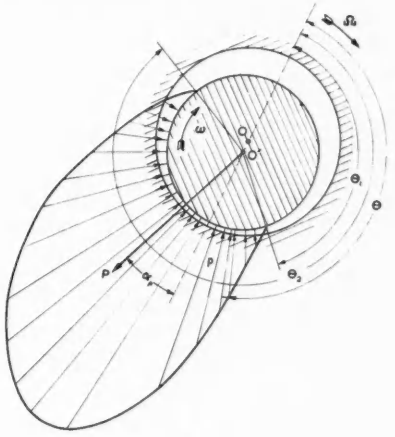

Fig. 1.

It is stressed that it is the angular velocity of the *centre-connecting line* that is being studied, i.e., the straight line connecting journal and bearing centres, and not that of load vectors.

The load-carrying capacity of the oil film in a geometrically correct bearing of considerable length at any instant is (see Fig. 1) :

$$P_0 = -\tfrac{1}{2}\int_{\theta_1}^{\theta_2} \rho\cos(\theta - \alpha_0)\,d\,d\theta \quad .. \quad (2)$$

*A. K. DYACHKOFF : A Study of Dynamically Loaded Bearings, Symposium IV, Friction and Wear in Machines, Ed. Akademia Nauk, S.S.S.R., 1949.

where P_0 is the load per unit length of the infinitely long bearing, and α_p = angle between vector of external load and centre-connecting line.

It follows that

$$P_0 = 3Z\left(\frac{d}{\eta}\right)^2 \epsilon^2 d \left\{ (\omega - 2\Omega) \int_{\theta_1}^{\theta_2} \left[\int_{\theta_1}^{\theta} \frac{\cos\theta_m - \cos\theta}{(\epsilon + \cos\theta)^3} d\theta \right] \times [-\cos(\theta - \alpha_p)]\, d\theta \right.$$

$$\left. + \frac{4\epsilon V_s}{\eta} \int_{\theta_1}^{\theta_2} \left[\int_{\theta_1}^{\theta} \frac{\sin\theta_m - \sin\theta}{(\epsilon + \cos\theta)^3} d\theta \right] \times [-\cos(\theta - \alpha_p)]\, d\theta \right\} \quad (3)$$

where θ_1 and θ_2 are the angles between the centre-connecting line and the radii to initial and end points of pressure formation in the oil film. Expression (3) is valid for any given instantaneous position of the centre-connecting line and of the respective variables which have an effect.

If a constant and uni-directional (" static ") load is applied, eq. (3) is transformed to

$$P_{0\,st} = 3Z\left(\frac{d}{\eta}\right)^2 \epsilon^2 d\omega \int_{\theta_1}^{\theta_2} \left[\int_{\theta_1}^{\theta} \frac{\cos\theta_m - \cos\theta}{(\epsilon + \cos\theta)^3} d\theta \right] \times [-\cos(\theta - \alpha_p)]\, d\theta \quad .. \quad (4)$$

If the angle α_p is replaced by α_c, measured in the opposite direction to that of α_p, eq. (4) becomes identical with the well-known expression of the classical hydrodynamic theory.

If a centrifugal load only is applied, eq. (3) is changed to :

$$P_{0\,c} = 3Z\left(\frac{d}{\eta}\right)^2 \epsilon^2 d\omega \int_{\theta_1}^{\theta_2} \left[\int_{\theta_1}^{\theta} \frac{\cos\theta - \cos\theta_m}{(\epsilon + \cos\theta)^3} d\theta \right] \times [-\cos(\theta - \alpha_p)]\, d\theta \quad .. \quad .. \quad (5)$$

Examining more complicated types of loading, it should be noted that the expression in the last line of eq. (3) takes account of variations in magnitude and direction of instantaneous loads. An analysis of the influence of this part on the load-carrying capacity of the oil film is difficult, chiefly because (a) the position of the centre-connecting line relative to the instantaneous external load is uncertain, and (b) because the limits of the load-carrying part of the oil film (θ_1 and θ_2) vary, dependent upon V_s and Ω/ω. An examination of angular movements reveals that the centre-connecting line rotates according to a law that may be quite different from that governing the rotation of the bearing load vector.

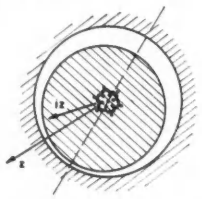

Fig. 2

When a constant uni-directional load is applied, the centre of the journal assumes a position such that the minimum oil film will be fixed relative to the bearing. Under a centrifugal force, the minimum oil film will take a fixed position in relation to the journal. The journal centre will describe a circle, the " basic circular trajectory". If, in addition to the centrifugal force, other forces are applied which rotate, say, twice as fast, the journal centre will move along the rotating centre-connecting line and its path will be an ellipse. If the additional forces rotate faster still, the path of the journal centre will be further distorted from the basic circular trajectory by elevations and depressions on both sides of that curve (Fig. 2). The additional motion of the journal centre along the centre-connecting line will create additional pressure in the oil film, which can be determined by the expression in the last line of eq. (3).

Experiments have been made on a special bearing-testing machine to examine the effect of forces additional to a centrifugal load. These forces were of second order, having the same sense of rotation as the journal, and of second and first order with the opposite sense of rotation. No static load was applied.

It was shown that, even with a considerable vector of the first order (1·36 times the centrifugal force) rotating in the opposite direction to the rotation of the journal, the centrifugal component was practically the sole factor determining bearing performance as indicated by eccentricity, heat development and oil flow through the bearing. The influence of the other components was within the limits of experimental error, i.e., approximately 3 per cent. Thus, the oil film offers considerable resistance to any force of an order different from the first, tending to displace it and to distort the original circular path of the journal centre under a centrifugal load only.

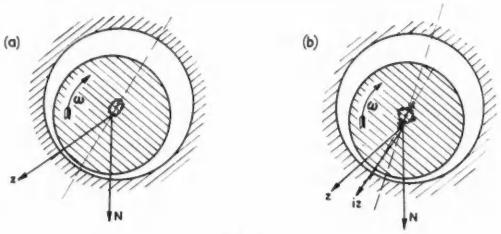

Fig. 3

If a static load is added to the centrifugal load, the trajectory of the journal centre will be an ellipse, the " basic elliptical trajectory " (see Fig. 3a). If, in addition, centrifugal forces of higher order are present, this elliptical path will be distorted as indicated in Fig. 3b.

The author has indicated in an earlier paper, in connection with the vectorial load diagram, the importance of the direction of the " effective impulse."

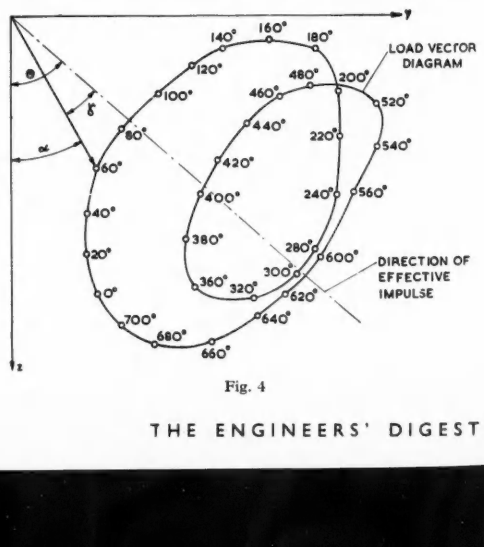

Fig. 4

This effective impulse was used to determine the position of the oil feed hole that would ensure the lowest possible bearing temperature. An explanation was also given of the influence of the " effective load " which follows from the magnitude of the effective impulse and has the same direction.

The following equations were obtained :—

$$I_{\text{eff}} = \frac{1}{\omega}\int_0^{\alpha_T} P^{\star} \cos\gamma \, d\alpha \quad .. \quad .. \quad (6)$$

$$\int_0^{\alpha_T} P^{\star} \sin\gamma \, d\alpha = 0 \quad .. \quad .. \quad (7)$$

$$P_{\text{eff}} = \frac{\int_0^{\alpha_T} P^{\star} \cos\gamma \, d\alpha}{\alpha_T} \quad .. \quad .. \quad (8)$$

$$K_{\text{eff}} = \frac{P_{\text{eff}}}{dl} \quad .. \quad .. \quad .. \quad (9)$$

where

I_{eff} = effective impulse,
P_{eff} = effective load,
$P^{\star}$ = instantaneous load,
γ = angle between direction of instantaneous load and direction of effective impulse, and
α_T = angle of rotation of journal during loading cycle.

It can easily be proved that the effective load determined by the load vector diagram related to the bearing is the static component of the bearing load, whereas the effective load determined by the load vector diagram in relation to the journal is the centrifugal componenc of the bearing load. Instantaneous forces acting upon the (rotating) journal and (static) bearing are of identical magnitude, but of different direction owing to the peculiar arrangement of co-ordinates fixed in the first case and rotating in the second case.

The magnitude of the effective load, if the co-ordinates z and y are used (see Fig. 4), is found to be :

$$P_{\text{eff}_z} = \frac{\int_0^{\alpha_T} P^{\star} \cos\alpha \, d\alpha}{\alpha_T} \quad .. \quad (10)$$

$$P_{\text{eff}_y} = \frac{\int_0^{\alpha_T} P^{\star} \sin\alpha \, d\alpha}{\alpha_T} \quad .. \quad (11)$$

hence $$P_{\text{eff}} = \sqrt{P_{\text{eff}_z} + P_{\text{eff}_y}} \quad .. \quad (12)$$

Its direction (identical with that of the effective impulse) is given by

$$\tan\Theta = \frac{\int_0^{\alpha_T} P^{\star} \sin\alpha \, d\alpha}{\int_0^{\alpha_T} P^{\star} \cos\alpha \, d\alpha} \quad .. \quad (13)$$

It is possible to imagine any given load pattern to be built up of the geometrical sum of suitable component load vectors. In general, it may be composed of a static vector of constant magnitude and direction

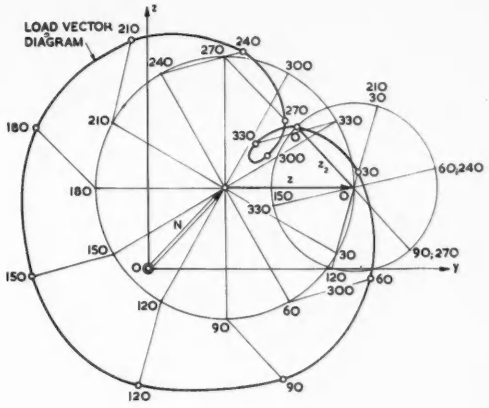

Fig. 5.

(" static component "), one vector rotating with the same speed as the journal (" centrifugal component ") and other vectors rotating at twice or three or more times the speed of the centrifugal component (see Fig. 5.)

The effects of vectors of second and higher order on the performance of a bearing under a centrifugal load, but without static load, have been mentioned to be negligible. With a static load, a centrifugal component and several components of higher order, the solution is more complex and requires special consideration. If the static and centrifugal components are of similar magnitude, the solution is most complicated, but if one of them is considerably greater than the other, the latter may be neglected.

II. CALCULATING BEARING LOADS IN PISTON ENGINES

To determine the best position of oil holes, it is necessary to estimate the magnitude and direction of the effective load for several operating conditions. This work can be greatly simplified by the use of suitable formulae.

The piston displacement as a function of crank angle is given by the following expression :

$$x = r\left\{\left(1 + \frac{1}{4}\lambda + \frac{3}{64}\lambda^3 + \frac{5}{256}\lambda^5\right) - \cos\alpha - \left(\frac{1}{4}\lambda + \frac{1}{16}\lambda^3 + \frac{15}{512}\lambda^5\right)\cos 2\alpha + \left(\frac{1}{64}\lambda^3 + \frac{3}{265}\lambda^5\right)\cos 4\alpha - \frac{1}{512}\lambda^5 \cos 6\alpha\right\} \quad .. \quad (14)$$

or $$x = Ar$$

where r is the crank radius,

$\lambda = r/L$ being the length of the connecting rod,
α = the angle of crank rotation from T.D.C. position (see Fig. 6).

The bearing load components are evaluated as the sum of the static and centrifugal forces due to gas pressures, the inertia forces of the reciprocating masses and the inertia forces of the rotating masses. For the static forces, fixed co-ordinates z_N and y_N are used (see Fig. 6). For the centrifugal forces the co-ordinates R and T will be used.

Instantaneous Gas Loads

For polytropic changes of state, the bearing loads occurring during the compression stroke are given by :—

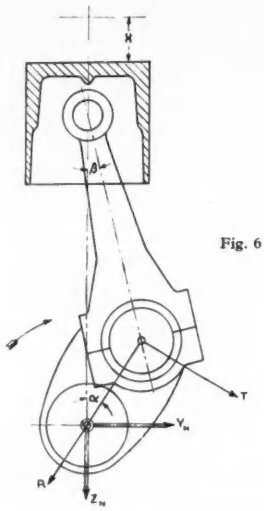

Fig. 6

$$p_{co} = p_c \frac{1}{\left[1 + A\,\frac{\epsilon_z - 1}{2}\right]^{n_1}} \qquad (15)$$

where p_c is the gas pressure at the end of compression (atm abs).

ϵ_z = compression ratio,
n_1 = polytropic exponent for compression,
and p_{co} = gas pressure during compression (atm abs) after a piston travel x.

For expansion, the corresponding expression is

$$p_{exp} = p_z \frac{1}{\left[1 + A\,\frac{\epsilon_z - 1}{2}\right]^{n_2}} \qquad .. \quad (16)$$

where p_z is the gas pressure at the instant at which ignition occurs (atm abs),

p_{exp} = gas pressure during expansion after piston travel x, and

n_2 = polytropic exponent for expansion.

Loads due to Connecting Rod Inertia

For simplicity, the conventional method is used, in which the connecting rod mass is replaced by two masses, one of which is concentrated at the position of the piston, the other rotating with the crankpin.

Loads due to the Inertia Forces of Reciprocating Masses

The equation for the acceleration of the reciprocating masses is based on eq. (14), from which the instantaneous inertia force is :—

$$P_j = -(m_p + m_c)\, r\omega^2 \left[\cos\alpha + \left(\lambda + \frac{1}{4}\lambda^3 + \frac{15}{128}\lambda^5\right)\cos 2\alpha - \left(\frac{1}{4}\lambda^3 + \frac{3}{16}\lambda^5\right)\cos 4\alpha + \frac{9}{128}\lambda^5 \cos 6\alpha \right] \qquad .. \quad .. \quad (17)$$

or $$P_j = -k_1(\cos\alpha + G_2 \cos 2\alpha + G_4 \cos 4\alpha + G_6 \cos 6\alpha) \qquad .. \quad .. \quad (17a)$$

where $$k_1 = (m_p + m_c)\, r\omega^2 \qquad .. \quad .. \quad (17b)$$

m_p = the mass of piston, piston rings and gudgeon pin, and m_c = the reciprocating portion of the connecting rod mass.

Magnitude of "Static" Load Component of Big End Bearing

The projection on the Z-axis of the "static" load component during compression may be expressed as :

$$Z_{NG\,co} = \frac{p_c}{\pi} \int_{\pi}^{2\pi} \frac{d\alpha}{\left[1 + A\,\frac{\epsilon_z - 1}{2}\right]^{n_1}} - 1 \qquad (18)$$

and for expansion :

$$Z_{NG\,exp} = \frac{p_z}{\pi} \int_{0}^{\pi} \frac{d\alpha}{\left[1 + A\,\frac{\epsilon_z - 1}{2}\right]^{n_2}} - 1 \qquad (19)$$

In general, the projection on the Z-axis of the gas force component during the working cycle will be :

$$Z_{NG} = \frac{D_1 p_c + D_2 p_z - 2}{2i} \qquad .. \quad (20)$$

where D_1 and D_2 are substituted for the fraction of eqs. (18) and (19), respectively, $i = 1$ for 2-stroke engines, and $i = 2$ for 4-stroke engines.

The projections on the Y-axis take the form :

$$Y_{NG\,co} = \frac{\int_{\pi}^{2\pi} p_{co} \tan\beta\, d\alpha}{\pi} - 1 \qquad .. \quad (21)$$

for the compression stroke, and

$$Y_{NG\,exp} = \frac{\int_{0}^{\pi} p_{exp} \tan\beta\, d\alpha}{\pi} - 1 \qquad .. \quad (21a)$$

for expansion. Introducing a power series to express $\tan\beta$ as a function of α and substituting I_1, I_2, etc., for the function of λ, it follows that

$$Y_{NG\,co} = \frac{p_c}{\pi} \int_{\pi}^{2\pi} \frac{(I_1 \sin\alpha + I_3 \sin 3\alpha \ldots.)\, d\alpha}{\left[1 + A\,\frac{\epsilon_z - 1}{2}\right]^{n_1}} - 1 \qquad (22)$$

and

$$Y_{NG\,exp} = \frac{p_z}{\pi} \int_{0}^{\pi} \frac{(I_1 \sin\alpha + I_3 \sin 3\alpha \ldots.)\, d\alpha}{\left[1 + A\,\frac{\epsilon_z - 1}{2}\right]^{n_2}} - 1 \qquad (23)$$

The general expression for the projection on the Y-axis of the "static" load component is :

$$Y_{NG} = \frac{Y_{NG\,exp} - Y_{NG\,co}}{2i} \qquad .. \quad (24)$$

The magnitude and direction of the "static" load component on the connecting rod big end bearing are calculated from Z_{NG} and Y_{NG} in the usual manner.

(To be continued)

The Reduction of Residual Stresses in Cold-Drawn Bars

By H. BUEHLER and E. H. SCHULZ. (From *Stahl und Eisen*, Vol. 70, No. 25, December 7, 1950, pp. 1147-1152, 22 illustrations.)

Residual stresses in cold-drawn bars can be reduced by 70 to 90 per cent if the drawn bar is subsequently cold-drawn with an area reduction of only 0·8 per cent or less. Surface quality and mechanical properties of the material remain unimpaired by this treatment, which is simple, economical, and superior to known stress-relief heat treatments. Cold-drawing and stress-relief drawing can be combined in one pass through two dies.

THE residual stresses in cold-drawn bars are usually undesirable. They may lead to cracking in service, during machining, or even in storage, or may cause distortions in unsymmetrical machining processes such as keyway cutting. They reduce the permissible working stresses and may endanger the safe functioning of the drawn component. Usually, therefore, an intermediate or final stress-relief heat treatment at controlled temperatures is introduced with the aim of reducing the residual drawing stresses without losing the improvements in strength obtained by cold work.

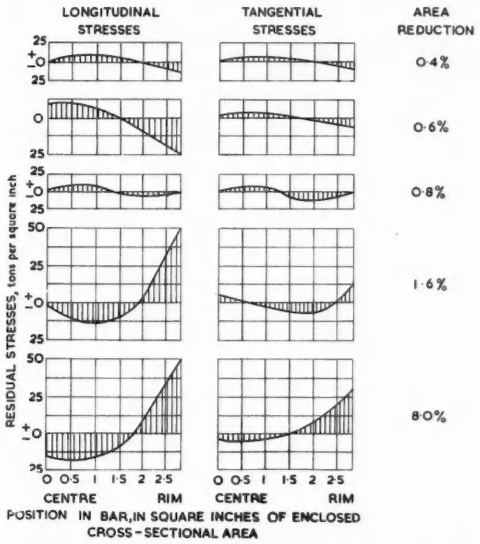

Fig. 1. **Influence of the amount of area reduction on the residual stress distribution in a cold-drawn round bar of 33-ton steel.**

It can, however, be shown by the method of Sachs[1] that not only the magnitude, but also the sign and distribution of these residual stresses depend on the amount of area reduction during cold-drawing. With normal rates of reduction, the skin of a drawn steel or brass bar is in tension and the core in compression, whilst at very low rates of reduction, the sign of the stresses is reversed (Fig. 1). Hence, if a cold-drawn bar, with tensile stresses at the skin, is subsequently cold-drawn very slightly, it can be expected that the skin tensile stresses will be reduced by superposition of the compressive stresses of the second drawing stage. This treatment has, in fact, proved successful[2], and may replace the usual heat treatment.

Laboratory and factory tests were undertaken on various materials (Table I). In factory tests, the bars were drawn in the normal manner, but in laboratory tests they were pressed through the die. The applied feed pressure was always far below the elastic limit of the material, so that a distortion of the resulting die stresses by the compression effect was avoided. After each drawing or pressing treatment, a length of the bar was

Table I. CHEMICAL COMPOSITION OF MATERIALS TESTED.

Material	Composition (per cent)						
	C	Si	Mn	P	S	Cu	Cr
24-ton steel	0·10	0·01	0·44	0·035	0·033	0·13	0·07
24-ton steel	0·18	0·01	0·47	0·024	0·045	0·18	trace
33-ton steel	0·19	0·45	0·93	0·041	0·026	0·68	0·43
38-ton steel	0·50	0·38	0·75	0·020	0·024	0·20	trace

	Cu	Zn	Sn	Pb
60/40 brass	58·25	38·92	0·11	2·54

bored out for the determination of the residual stresses, whilst the remaining bar was subjected to further cold deformation. In some cases, even a third reduction was investigated. The stress-reducing effect on a 33-ton steel bar (Table I) is evident from Fig. 2: Normal cold-drawing from 1·969 to 1·890 in. (50 to 48 mm) diameter creates longitudinal tensile stresses of 34 tsi at the surface. These stresses decrease to 9·5 tsi in a first stress-relief reduction from 1·890 to 1·882 in. diameter, and to 7·5 tsi in a second stress-relief reduction from 1·882 to 1·880 in. diameter. The tangential stresses are similarly diminished. The stresses in the core of the bar are not increased, and the longitudinal core stresses are even appreciably reduced by the second stress-relief treatment. That this stress reduction is due to the imposition of compressive stresses produced by an area reduction of less than 0·8 per cent (Fig. 1), is proved by

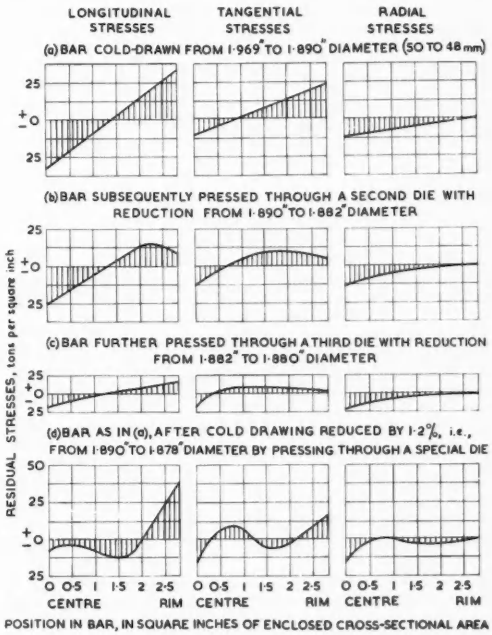
LONGITUDINAL STRESSES
TANGENTIAL STRESSES
RADIAL STRESSES
(a) BAR COLD-DRAWN FROM 1·969" TO 1·890" DIAMETER (50 TO 48 mm)
(b) BAR SUBSEQUENTLY PRESSED THROUGH A SECOND DIE WITH REDUCTION FROM 1·890" TO 1·882" DIAMETER
(c) BAR FURTHER PRESSED THROUGH A THIRD DIE WITH REDUCTION FROM 1·882" TO 1·880" DIAMETER
(d) BAR AS IN (c), AFTER COLD DRAWING REDUCED BY 1·2%, i.e., FROM 1·890" TO 1·878" DIAMETER BY PRESSING THROUGH A SPECIAL DIE
RESIDUAL STRESSES, tons per square inch
CENTRE
RIM
POSITION IN BAR, IN SQUARE INCHES OF ENCLOSED CROSS-SECTIONAL AREA

Fig. 2. **Residual stresses after cold-drawing and subsequent stress-relief treatment of a 33-ton steel bar of about 2 in. diameter.**

Fig. 2(d). If the amount of area reduction in the stress-relief treatment is stepped up to 1·2 per cent, the tensile skin stresses in the cold-drawn bar are increased, not reduced, because additional tensile stresses are then created and superimposed. In fact, the longitudinal skin stresses of the bar of Fig. 2(a) are seen to increase by about 6 tsi.

24-ton steel (0·1 C, Table I) can be similarly stress-relieved (Fig. 3): The longitudinal skin stresses are very much reduced and the tangential skin stresses even changed into slight compression stresses. Another 24-ton steel bar (0·18 C, Table I) of 6 ft length was cold-drawn from 1·969 to 1·890 in. diameter and then stress-relief *drawn* to 1·886 in. diameter. The stress-relief

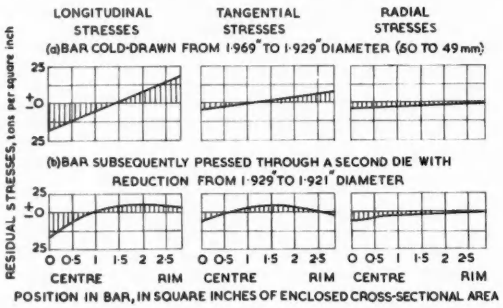
LONGITUDINAL STRESSES
TANGENTIAL STRESSES
RADIAL STRESSES
(a) BAR COLD-DRAWN FROM 1·969" TO 1·929" DIAMETER (50 TO 49 mm)
(b) BAR SUBSEQUENTLY PRESSED THROUGH A SECOND DIE WITH REDUCTION FROM 1·929" TO 1·921" DIAMETER
RESIDUAL STRESSES, tons per square inch
25
+0
25
0 0·5 1 1·5 2 2·5
CENTRE
RIM
POSITION IN BAR, IN SQUARE INCHES OF ENCLOSED CROSS-SECTIONAL AREA

Fig. 3. **Residual stresses after cold-drawing and subsequent stress-relief treatment of a 24-ton steel bar (0·1 per cent C) of about 2 in. diameter.**

treatment reduced the longitudinal skin stresses from 27 to 4·5 tsi tension and the tangential skin stresses from 20 to 5 tsi tension. Both drawing stages were then combined into one operation, and a bar drawn through two dies, 1·890 and 1·886 in. in diameter, arranged in series at a distance of two inches so that the bar could be lubricated between the two drawing stages. The final longitudinal skin stress was again only 4 tsi. The distance between the two dies could probably be further reduced, and the tapered end of the bar shortened, if the lubrication arrangement were adapted accordingly. The test was repeated, first in separate stages, then in one operation, with a smaller stress-relief die of 1·882 in. diameter. The stress relief was nearly as efficient as before, the final skin stresses being 12 tsi longitudinally and 9 tsi tangentially. Finally, a 38-tons steel bar (Table I) of 1·969 in. diameter was similarly cold-drawn to 1·890 in. diameter and stress-relief *drawn* in two separate stages as well as in one operation. Fig. 4 illustrates the stress relief obtained with a second die of 1·886 in. diameter or, alternatively, 1·882 in. diameter. The longitudinal skin stresses of 47 tsi due to cold-drawing were reduced to slightly over 13 tsi by the smaller stress-relief die, and to less than 13 tsi by the larger stress-relief die. Tests on hexagonal bars of 1 inch width across flats were equally successful.

Stress-relief drawing thus reduces the high residual stresses due to normal cold-drawing by 80 per cent in 24-ton steel (0·1 C), and by 70 per cent in 38-ton steel. The stress relief is not noticeably diminished if the diametral reduction used is 0·008 inch (in about 2 inches) instead of only 0·004 inch; a certain wear of the stress-relief die, therefore, does not materially impair the beneficial effect obtained. Drawing for stress relief (Fig. 4) is definitely to be preferred to pressing (Figs. 2 and 3), since it reduces not only the skin stresses, but also the stresses across the entire cross-section in a uniform manner. The permanent deformations obtained by pressing seem to resemble those produced by surface rolling and to be limited to the surface layers. The

TABLE II. TENSILE TEST PROPERTIES (AVERAGE VALUES) OF BARS COLD-DRAWN FROM 1·969 TO 1·890 IN. DIAMETER AND THEN STRESS-RELIEF DRAWN TO VARIOUS DIAMETERS.

Material	Dia. of stress relief die, in.	0·03% proof stress (elast. limit) tsi	0·2% proof stress (yield limit) tsi	Ultimate stress tsi	Elongation on 10 × dia. %	Area restriction %
24-ton steel	—	27·5	31·2	33·2	9·1	58
	1·886	31·6	33·3	35·0	8·3	53
	1·886*	30·0	31·0	33·0	10·3	56
	1·882	31·1	32·8	33·8	8·2	54
	1·882*	29·1	30·4	32·4	9·8	56
38-ton steel	—	38·1	48·3	52·0	6·1	33
	1·886	46·2	50·8	52·0	4·6	33
	1·882	46·2	51·8	52·8	5·1	32
	1·882*	44·8	50·6	51·7	5·4	35

*Cold-drawing and stress-relief drawing combined in one operation.

small amount of area reduction required for the stress-relief stage demands close tolerances on the nominal difference in diameter of main die and stress-relief die and, therefore, accurate manufacture of the relief die. This will present no difficulties to the ordinary tool room if the difference in diameters exceeds 0·002 in., so that bars from $\frac{3}{4}$ in. up to the largest diameters can successfully be relief-drawn under normal workshop conditions. With specially accurate die-manufacturing methods, even smaller bars can be so treated.

The *power* required for stress-relief drawing, i.e., for diametral reductions of less than 0·008 in. on bars of about 2 in. diameter, was found by measurement to be very small. Where cold-drawing and stress-relief drawing are combined in one stage, the increase in power requirements is negligible. The *surface finish* of the stress-relieved bar, although expected to be as good as that of a normally cold-drawn bar, was nevertheless checked in two independent factories. If any difference was noted, it was rather to the advantage of the stress-relieved bar. The *mechanical properties* remain unimpaired by stress-relief drawing (Table II). The elastic limit (0·03 per cent proof stress) is even increased by as much as 6·5 tsi for the 38-ton steel. Since the test pieces were cut out of surface layers, this improvement can be explained by the repeated cold deformation which usually increases the elastic limit more than the yield or ultimate stress.

A normal stress-relief heat treatment, if carried out at 400° C for 2 hours, reduces the maximum residual stresses in a drawn 24-ton (0·18 C) steel bar of about 2 in. diameter from 38 to about 21 tsi. Heating at

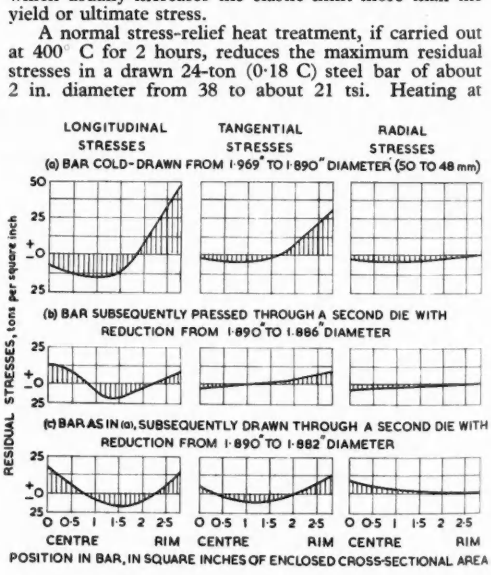
LONGITUDINAL STRESSES
TANGENTIAL STRESSES
RADIAL STRESSES
(a) BAR COLD-DRAWN FROM 1·969" TO 1·890" DIAMETER (50 TO 48 mm)
(b) BAR SUBSEQUENTLY PRESSED THROUGH A SECOND DIE WITH REDUCTION FROM 1·890" TO 1·886" DIAMETER
(c) BAR AS IN (a), SUBSEQUENTLY DRAWN THROUGH A SECOND DIE WITH REDUCTION FROM 1·890" TO 1·882" DIAMETER
RESIDUAL STRESSES, tons per square inch
50
25
+0
25
0 0·5 1 1·5 2 2·5
CENTRE
RIM
POSITION IN BAR, IN SQUARE INCHES OF ENCLOSED CROSS-SECTIONAL AREA

Fig. 4. **Residual stresses after cold-drawing and subsequent stress-relief drawing, by two alternative methods, of a 32-ton steel bar of about 2 in. diameter.**

TABLE III. COMPARISON OF STRESS-RELIEF DRAWING WITH HEAT TREATMENT. MAXIMUM RESIDUAL STRESSES IN STRESS-RELIEVED MATERIAL, AND ESTIMATED MANUFACTURING COSTS, IN PER CENT OF VALUES OBTAINED WITHOUT STRESS-RELIEF TREATMENT.

Material	Cold-drawn only from 1·969 to 1·890 in. dia.	Heated to 400° C after drawing	Drawn from 1·969 to 1·929 in. dia., stress-relieved at 620° C, finally drawn to 1·890 in. dia.	Stress-relief drawn after cold-drawing	Drawn and stress-relief drawn in one operation
	Maximum residual stresses after treatment				
24-ton steel	100	60	80	20	20
38-ton steel	100	60	90	35	30
	Manufacturing costs				
24 and 38 ton steels	100	290	370	122	122

500° C reduces the stresses to 2·5 tsi, but also impairs the mechanical strength and surface finish of the cold-drawn bar. A heat treatment above 400° C is therefore seldom possible, and the stress relief will be incomplete. If heat treatment is given between drawing stages only, the residual stresses of the last stage will remain in the material. These are already very high for area reductions of 2 per cent (Fig. 1), so that under workshop conditions, high stresses can hardly be avoided by intermediate heat treatment. A comparison of residual stresses and estimated manufacturing costs (Table III) shows clearly that the stress-relief drawing treatment is superior in all respects to the heat treatment, even if mass production should appreciably reduce the high costs of the latter.

The fundamental beneficial effect of stress-relief drawing or pressing through a die can also be obtained by other forms of cold work that impart a limited uniform permanent deformation to the surface layers of the material. However, cold work that only deforms a thin surface layer, e.g., surface rolling or press-polishing, will have a much smaller stress-reducing effect than the stress-relief drawing suggested here. Further preliminary tests on bars of various sizes, materials, and shapes (round, hexagonal, etc.) must precede full-scale application of this treatment, and should aim at establishing accurate data regarding the permissible, and the most efficient, area reduction for stress relief, i.e., regarding the most advantageous differences in diameter between main die and stress-relief die. Since the amount of stress relief is different for soft and hard materials, test results should be available for at least one soft and one hard material.

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(1) G. SACHS, *Z. Metallkunde*, 19 (1927), p. 352-357.
(2) H. BUEHLER, "The reduction of residual stresses in cold drawn steel bars," *Ferrous Metallurgy*, Vol. 1, Bielefeld 1948, p. 247. Brit. Patent No. 423,868.

AUSTRIA

The Physical Characteristics of D.C. Generators

By R. BRÜDERLINK and K. GEIGENMÜLLER. (From *Elektrotechnik und Maschinenbau*, Vol. 67, No. 11, November, 1950, pp. 332-341, 16 illustrations.)

D.C. generators used for arc welding must possess special static and dynamic characteristics. These can be obtained by various means. Design features have been developed which enable machines to fulfil both types of requirements.

STATIC AND DYNAMIC REQUIREMENTS FOR WELDING MACHINES

1. *Static requirements* : Fig. 1 shows four different characteristics representing the variation of the voltage U as a function of the current I. These curves can be obtained with normal generators provided with simple additional devices. The dotted line represents the arc characteristic. It was long considered that curve 3, which has a steep downwards slope near the operating point, was the most favourable, since it ensures constant current under steady load conditions. This view has since been abandoned, and preference is now given to curves similar to lines 2 or 1. Although with these the current is not constant, the power fluctuations occurring in the arc are reduced. A characteristic such as that of curve 4 can only be employed if the current has the tendency to revert to lower values for voltages below the operating voltage, although even then this characteristic cannot be regarded as particularly suitable.

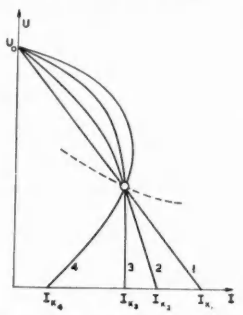


Fig. 1. (left) **Various static characteristics.**

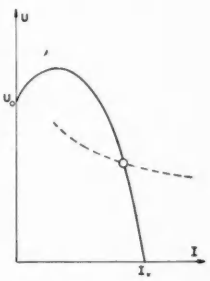


Fig. 2. (right) **Static characteristic of a machine with series-compound winding.**

The open-circuit voltage U_0 is limited by considerations regarding the safety of the operator to a maximum value generally of the order of 60 volts. Voltages below 40 volts lead to difficulties in striking the arc or when operating with heavily coated electrodes. Fig. 2 shows a characteristic obtained particularly with constant-current machines. This shape is not, however, typical of the machine but of the series-excitation. Machines having no constant-current system, but with partial series excitation, have similar characteristics. With machines of this type, the open-circuit voltage U_0 can be reduced to 30 volts, or even lower, but the maximum voltage must still be high enough to obtain a stable point of intersection with the arc characteristic.

2. *Dynamic requirements* : The importance of the dynamic behaviour is based on the fact that in welding, particularly with unprotected electrodes, short-circuits occur in rapid succession (approximately 15 to 25 per second), through metal globules. One can, therefore, no longer speak of steady operating conditions. The welding operation is, in fact, a succession of transient processes, which frequently overlap, Thus, the phenomena which are important in the welding operation cannot be determined from the static characteristics (Figs. 1 and 2), which only lead to misinterpretation of results. For welding work, the dynamic behaviour is

the primary consideration. Furthermore, the arc characteristic itself is not a clearly defined line but fluctuates within certain limits, so that it is more appropriate to use the term " arc area."

The dynamic behaviour resulting from all the transient processes is of a complicated nature. The transient phenomena are due to resistance variations occurring in the arc, which are not controllable and non-reproducible in frequency or magnitude. To study these phenomena, it will therefore be most convenient to consider the two extreme conditions corresponding to sudden short-circuit and open circuit. Oscillograph recordings of the voltage and current variations for these two conditions are easily obtainable* and have the advantage of giving well-determined reproducible results.

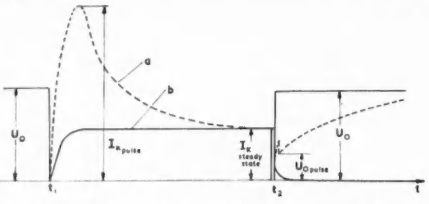


Fig. 3. **Dotted lines:—" Off-on-Off " diagram of a machine with unsuitable dynamic characteristics. Solid lines:—" Off-on-Off " diagram of a machine with ideal dynamic characteristics.**

The dotted lines " a " of Fig. 3 are open-circuit/short-circuit/open-circuit oscillograms (" off-on-off " recordings) of a generator having a static characteristic similar to curve 2 in Fig. 1. As regards static behaviour this generator is therefore suitable for welding work. A static characteristic of this type is achievable with a generator of normal design by using, for instance, separate excitation and a series-compound (" SC ") winding. Considering again the curves " a " of Fig. 3, it can be seen that up to the time t_1 the machine was operating on open circuit at a voltage U_0. Short-circuiting occurred at t_1 and, after reaching a steady state in this condition, the circuit was opened at time t_2.

On short-circuiting, the current rises rapidly to a maximum value I_{sp} and then falls off more gradually down to its steady-state value I_{ss}. This latter value can be read off the static characteristic, which cannot, however, be used for I_{sp}. On reverting to open circuit at time t_2, the current falls off very rapidly to zero. With an ideal switching device, the drop to zero would be instantaneous.

The open-circuit voltage U_0 can also be determined from the static characteristic. It drops instantaneously to zero on short-circuiting. When switching to open circuit, there is a voltage peak, but the open-circuit voltage drops down again to the value U_{op} as soon as the current is completely cut-off, and then rises at relatively slower rate to its initial value U_0. The value of U_{op} cannot be found from the static characteristic. The voltage peak mentioned above is a general phenomenon, which occurs whenever an inductive short-circuit is switched out. It has nothing to do with the qualities of the machine as a welding generator and gives, in fact, only an indication of the quality of the switching device, so that it will be omitted from further considerations. The curve of increasing voltage from U_{op} to U_0 would be, if saturation effects were neglected, an exponential curve with the time-constant of the separate excitation coil.

The " off-on-off " diagram of this machine shows that it is not suitable for welding work. To fulfil the dynamic requirements, the " off-on-off " diagrams must show curves similar to the curves " b " of Fig. 3. These may be regarded as the ideal " off-on-off " diagram for all machines with a steadily falling static characteristic as indicated in Fig. 1.

The ideal diagram differs from the previous one in two respects : (i) the open-circuit voltage reappears suddenly as soon as the short-circuit is cut out, so that

$$U_{op} = U_0 \quad .. \quad .. \quad (1)$$

and (ii) the current on short-circuiting does not exceed its steady-state value ; a true current impulse is not obtained, and we thus have

$$I_{sp} = I_{ss} \quad .. \quad .. \quad .. \quad (2)$$

Equations (1) and (2) express, therefore, the requirements which a welding machine should fulfil in order to have a good dynamic behaviour. Obviously, one cannot ask for more than that the full open-circuit voltage should be reached again instantaneously after cutting-off the short-circuit. Whatever the resistance variations may be, the current and voltage assume instantaneous values corresponding to the new *static* operating point, the current and voltage varying continuously in the same direction, that is, without passing through extreme values. The suggestion that there should be no current peak or maximum between the two static conditions, since it makes smooth welding operations difficult, cannot easily be dismissed, although the elimination of the current pulse is not so important as the instantaneous recovery of voltage. The requirement regarding the current pulse has been regarded as being of fundamental importance in all previous literature on this subject, because there is a close physical relationship between the two requirements (i) and (ii), so that, when (ii) is fulfilled, (i) is also satisfied.

In the case of machines operating exclusively or partly with series-field excitation and having a low U_o voltage, a dynamic behaviour of the type illustrated by diagram " b " of Fig. 3 is not sufficient. In the following section, various arrangements will be considered, in order to determine the extent to which they fulfil the two criteria which have been formulated.

STATIC AND DYNAMIC BEHAVIOUR OF VARIOUS ARRANGEMENTS

1. *Resistance welding with constant voltage supplied from the mains* : The circuit is shown in Fig. 4a. Its static characteristics (Figs. 4b) are giben by

$$U = U_0 - RI \quad .. \quad .. \quad (3)$$

The static and the dynamic behaviour are in this case identical, since the circuit cannot produce free oscillations with a finite time-constant. The " off-on-off " diagram is of the same type as curves " b " in Fig. 3. When the short-circuit is cut out, U_0 is reached immediately, and the short-circuit current never exceeds the value I_{ss}. If a higher value is chosen for the ratio U_0/U, the ratio I_s/I becomes lower, and the security that the arc will not break will be correspondingly greater, but this leads to a lower efficiency, since $\eta = U/U_0$.

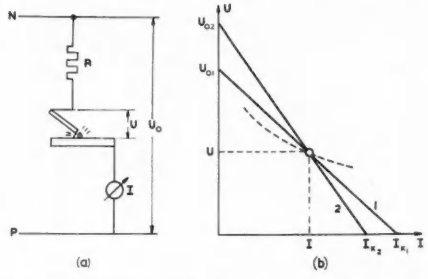


Fig. 4. **Resistance welding with constant voltage supplied from the mains.**

*See, for example : GRABNER, *Elektr. u. Maschinenbau*, Vol. 53, 1935, p. 4.

2. *Welding with constant mains supply voltage, using a series-wound machine* : This arrangement, shown in Fig. 5, is similar to the previous one in its static and dynamic characteristics. The circuit is supplied from a three-phase network (1) and comprises a driving motor (2), a d.c. generator (3) of normal design, delivering the approximately constant voltage U_o, and a series-wound machine (4), which produces a voltage approximately proportional to the current and acts in the same way as the resistance in the previous case, the difference being that it does not waste the power $(U_o\text{-}U)I$ in the form of heat, but transmits it to the shaft. With saturation, however, the machine is equivalent to a resistance which becomes smaller for higher values of current. This does not affect its dynamic behaviour, although it results in a slight deterioration of the static behaviour as the characteristic assumes a hyperbolic shape. Moreover, with this arrangement, the inductive effect is also apparent, owing to the inductances of the exciting and armature circuits of the series-wound machine (4). On short-circuiting, the current does not rise suddenly but follows an exponential curve in reaching its steady-state value ; furthermore, a switch voltage peak appears on breaking-off. Despite these minor variations, the system complies with the requirements and definitely has favourable dynamic characteristics.

3. *Similar circuit for d.c. network* : If a d.c. network of suitable voltage is available, the basic principle described above can be achieved with two machines (Fig. 6), viz., a normal shunt-field machine (1) and a normal non-saturated series-field machine (2). No power is wasted and the system has ideal " off-on-off " characteristics.

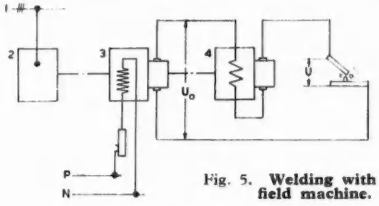


Fig. 5. **Welding with a series-field machine.**

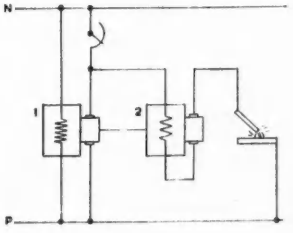


Fig. 6. **D.c. version of arrangement of Fig. 5.**

4. *Separately-excited generator with series-compound (" SC ") winding* : The static characteristic of this machine is easily derived from its no-load curve. The open-circuit voltage U_0 corresponds to the value chosen for the exciting current i_e (Fig. 7). Under load, the ampere-turns Iw_y of the series winding are subtracted from the constant separate-field excitation $i_e w_f$. Making due allowance for changes in scale, the static characteristic is, therefore, a mirror image of the no-load curve with respect to the vertical axis. Its curvature and slope near the operating point will thus be greater with increased saturation of the machine. For a non-saturated machine, the characteristic would be a straight line. The machine would then operate acording to the curves " a " of Fig. 2 and its " off-on-off " diagram characteristics would make it unsuitable for welding.

The pulse voltage U_{op} is smaller than U_0 and the

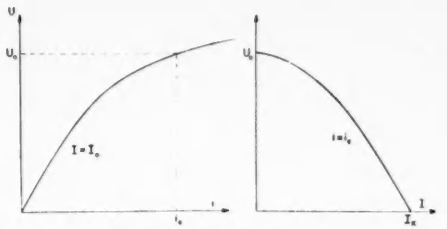


Fig. 7. **Open-circuit (I = 0) characteristic and static ($i = i_e$) characteristic for a separately excited generator with series-compound winding.**

pulse current I_{sp} is greater than I_{ss} in this case, for the following reasons :—Under *no-load* conditions, the main flux is excited by the external exciting current i_e. This current, the main flux and the induced voltage are all simultaneously present. Under *load*, and even more so under short-circuit conditions, the main flux, owing to the effect of the SC winding, is reduced to a very low value, corresponding to the internal voltage drop when short-circuit occurs. Under permanent short-circuit conditions, the exciting current has its no-load value i_e. The residual field, with a flux corresponding to $i_e w_f\text{-}Iw_y$, cannot change when the short-circuit is broken off, owing to its linkage with the closed separate field winding. The exciting current is, therefore, suddenly brought down from i_e to $i_e - I(w_y/w_f)$ and then rises again to the no-load value i_e (Fig. 8) according to the time-constant of the external exciting circuit. A pulse voltage U_{op} occurs suddenly as the current falls off, and the voltage then rises to its final value U_0 following the same time law.

In a machine without a series-compound winding, the armature current on short-circuiting would tend to reach the full value of the permanent short-circuit current, with an exponential rise determined by the time-constant of the armature current, but no current peak due to short-circuiting. The SC winding has the effect of considerably reducing the permanent short-circuit current, but gives rise to a short-circuit current pulse. This can be explained as follows :—The rise of the armature current in the SC winding induces in the separate exciting coil a back-e.m.f. $d(MI)/dt$ which assists the steady exciting voltage and, therefore, temporarily raises the exciting current i_e to a higher value, so that the main flux will not fall off immediately to the small value which it reaches under the permanent short-circuit.

Thus, the SC winding reduces the short-circuit current but produces a current pulse. For the dynamic behaviour of the system, the absolute value of this pulse is less important than its relative value, compared with that of the permanent short-circuit current. The current pulse can be eliminated by taking suitable measures to maintain the exciting current absolutely constant at all times.

To maintain the exciting current at a constant value throughout the operation, two decoupling methods can be employed, viz. : (1) the ohmic resistance in the exciting circuit is made so high that the ohmic potential drops will be far greater than the inductive voltages ; (2) the mutual induction effect between the armature circuit and the separate exciting circuit is artificially suppressed.

The effects of both methods are : (1) the time constant of the exciting circuit is reduced and the voltage reaches the value U_0 much more rapidly when the short-circuit is opened ; (2) with complete decoupling, the inductive effect of the variable armature current on the separate excitation current is eliminated ; the latter therefore remains constant, and the voltage also rises immediately to the value U_0.

The previously formulated requirements (i) and (ii)

are therefore fulfilled by either method. They are obviously interdependent and can be expressed as a single requirement (iii):— The armature circuit should not have any inductive effect on the separate excitation circuit, that is, the decoupling of these circuit should be complete.

5. *Separately-excited generator with SC winding decoupled by a high resistance in the exciting circuit* : Fig. 8 shows the variation of the exciting current for

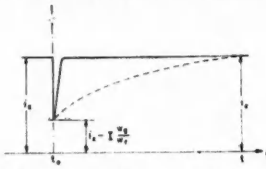


Fig. 8. **Dotted curve: Exciting current on switching-out the short-circuit of a normal separately excited generator with series-compound winding.**
Solid curve: Exciting current of machine with decoupling arrangement on switching-out from short circuit.

this case, when the short-circuit is opened. The recurring voltage has the same type of characteristic. No short-circuit current pulse occurs ; the ideal " off-on-off " diagram conditions are obtained, but at the expense of heavy losses in the exciting circuit.

6. *Separately-excited generator with SC winding provided with a decoupling transformer* : The mutual inductance M between the separate exciting circuit and the armature circuit can be cancelled out by arranging a decoupling transformer with the same mutual inductance value, as shown in Fig. 9. The voltage reaches U_n instantaneously, since the current in the exciting winding is no longer subjected to inductive effects from the armature circuit and, therefore, remains absolutely constant. No short-circuit current pulse occurs, and ideal " off-on-off " diagram conditions are obtained.

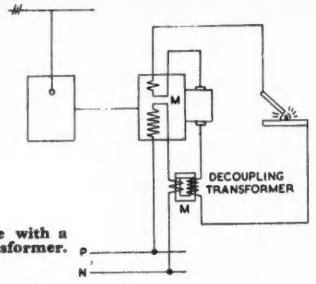


Fig. 9. **Machine with a decoupling transformer.**

The provision of a decoupling transformer represents, however, a considerable increase in the weight of the equipment. A transformer with a large air-gap and a considerable amount of iron and copper is required, because the separate exciting current and the armature current produce opposite magnetising effects, and additive fluxes in the transformer. For this reason, many endeavours have been made to obtain specific welding characteristics by incorporating suitable features in the design of the machine.

7. *Stray pole machine* : A simple explanation of its operation is as follows :—The stray pole constitutes a magnetic shunt in connection with the armature (see Fig. 10a). Its effect can be adjusted by varying the air-gap δ_s. Under *no-load* conditions, only a comparatively small portion of the yoke or pole flux is deviated from the armature, and the no-load voltage is reduced by a corresponding amount. Under *load*, the stray pole is also excited by the auxiliary windings, so that a larger portion of the main flux is now removed from the armature. Thus, the stray pole also alters the shape of the static load characteristic. Finally, under *short-circuit* conditions, the major portion of the main flux is taken from the armature. On opening the short-circuit, the permanent no-load condition is obtained immediately, assuming that the total flux through the exciting winding is at all times constant.

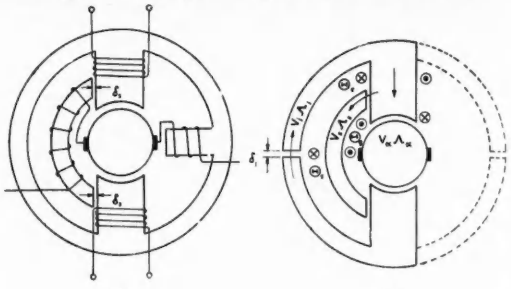


Fig. 10. **Principle of a stray pole machine.**

Although this simple explanation is substantially correct, a more detailed study shows that the stray poles have more complex effects. In Fig. 10b, the right-hand side of the yoke is drawn in dotted lines, to indicate that it can be omitted, in principle, on assuming that the left-hand side has been doubled in its cross-section. For clarity, the change pole has been omitted from the figure, although its influence cannot be neglected in an accurate investigation. Finally, a series-compound winding is assumed to be included in the system, in order to take account of this further possibility in the calculation. Instead of this winding, a brush displacement in the direction of rotation would produce the same effect. In connection with the effect of the stray poles, the yoke saturation which is associated with a corresponding magnetic potential should also be considered. This magnetic potential can be taken into account by introducing a fictitious equivalent air-gap of width δ_j in the calculations. The other magnetic potentials in the iron are neglected.

The flux linkage law gives the following relations between the magnetic potentials V and the induced ampere-turns Θ :

$$V_j + V_s = \Theta_e + \Theta_g \; ; \; V_j + V_a = \Theta_e - \Theta_g \; ;$$
$$V_s - V_a = \Theta_s + \Theta_g. \qquad .. \qquad (4)$$

where $\Theta_e = i_e w_e$, $\Theta_s = Iw_s$, and $\Theta_g = Iw_g$.

These equations are not independent but related to each other by

$$\Phi_j = \Phi_a + \Phi_s \qquad .. \qquad .. \qquad (5)$$

The permeances are

$$\Lambda_a = \mu_o F_a/(2\delta_a), \quad \Lambda_s = \mu_o F_s/(2\delta_s) \text{ and}$$
$$\Lambda_j = \mu_o F_j/\delta_j \qquad .. \qquad .. \qquad (6)$$

where F_a, F_s, and F_j, are the cross-sectional areas of the corresponding air-gaps, and Φ_a, Φ_s, Φ_j = flux entering the armature, stray flux, and yoke flux, respectively. The yoke flux also goes through the exciting winding. As, generally, $\Phi = \Lambda V$, this gives the following expressions :

$$\left.\begin{aligned} \Phi_a &= \Lambda_a[\Lambda_j \Theta_e - \Lambda_s \Theta_s - (\Lambda_s + \Lambda_j)\,\Theta_g]/\Sigma\Lambda \\ \Phi_s &= \Lambda_s[\Lambda_j \Theta_e + (\Lambda_j + \Lambda_a)\,\Theta_s + \Lambda_a \Theta_g]/\Sigma\Lambda \\ \Phi_j &= \Lambda_j[(\Lambda_s + \Lambda_a)\,\Theta_e + \Lambda_s \Theta_s - \Lambda_a \Theta_g]/\Sigma\Lambda \end{aligned}\right\} \quad (7)$$

where $\Sigma\Lambda = \Lambda_j + \Lambda_s + \Lambda_a$.

Under no-load conditions, when $\Phi_s = 0$ and $\Phi_g = 0$, the values of the fluxes are

$$\Phi_{a0} = \Lambda_a \Lambda_j \Theta_{e0}/\Sigma\Lambda \; ; \; \Phi_{s0} = \Lambda_s \Lambda_j \Theta_{e0}/\Sigma\Lambda \; ;$$
$$\Phi_{j0} = \Lambda_j(\Lambda_s + \Lambda_a)\,\Theta_{e0}/\Sigma\Lambda \qquad .. \qquad (7a)$$

(To be continued.)

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

INTERNAL COMBUSTION ENGINES

Radial Engine with Variable Compression

By G. S. HOELL. (From *Automotive Industries, U.S.A.*, Vol. 103, No. 11, December 1, 1950, pp. 45 and 102, 6 illustrations.)

AT the beginning of World War II it became apparent that production of fuel for aero-engines had to be stepped up considerably and at an ever increasing rate to meet the demand for high-octane fuel. If the compression ratio of the engine cylinders could be varied by the pilot during flight, not only could he fly at an optimum rate of fuel consumption, essentially a function of altitude and speed, but he could thereby increase his cruising radius considerably with a given load of fuel.

In developing this feature, the generally accepted system of employing a master connecting rod, the crank end of which moves as any usual connecting rod while the remaining rods do not, had to be discarded. In the place of this system, a disc, such as *A* in Fig. 1, is suspended on three or more links of equal length *R*; the disc can perform a translatory and rotational motion in such a way that any random point *B* of the disc will move around a centre *C* of a circle, the radius of which is *R* and the centre line of which is parallel with the centre lines of the links.

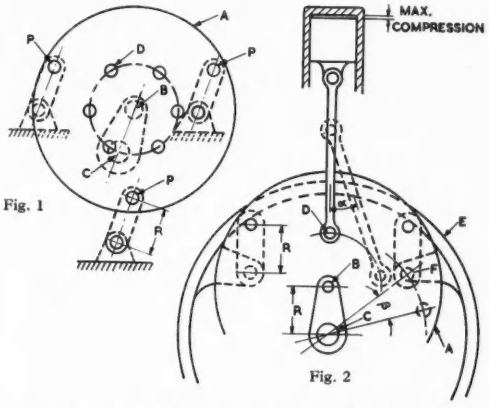


Fig. 1

Fig. 2

If the point *B* is chosen as the geometrical centre of the link pins *P*, then this centre may be chosen as the wrist pin centre of a crank turning around centre *C*. The disc *A* can now be provided with evenly spaced auxiliary wrist pins *D*, to which connecting rods from radial engine cylinders may be attached. Such arrangement is indicated schematically in Fig. 2. The disc *A* must naturally be balanced, but the motions of all connecting rods are identical (except for phase difference).

The compression ratio is made adjustable during flight by turning the link centres *F*, Fig. 2, around the crankshaft centre *C*. These centres are located in a ring *E* which is mounted in the rigid framework and can be rotated through proper mechanism by the pilot. When turned by an angle β the piston is drawn away from its top position, and as long as the ring is fixed in this position, the piston will continue to operate with reduced compression.

METALLURGICAL ENGINEERING

The Oxidation of Heat-Resistant Alloys in the Presence of Foreign Oxides

By J. L. MEIJERING and G. W. RATHENAU. (From *Philips Technical Review, Holland*, Vol. 12, No. 8, February, 1951, pp. 213-220, 10 illustrations.)

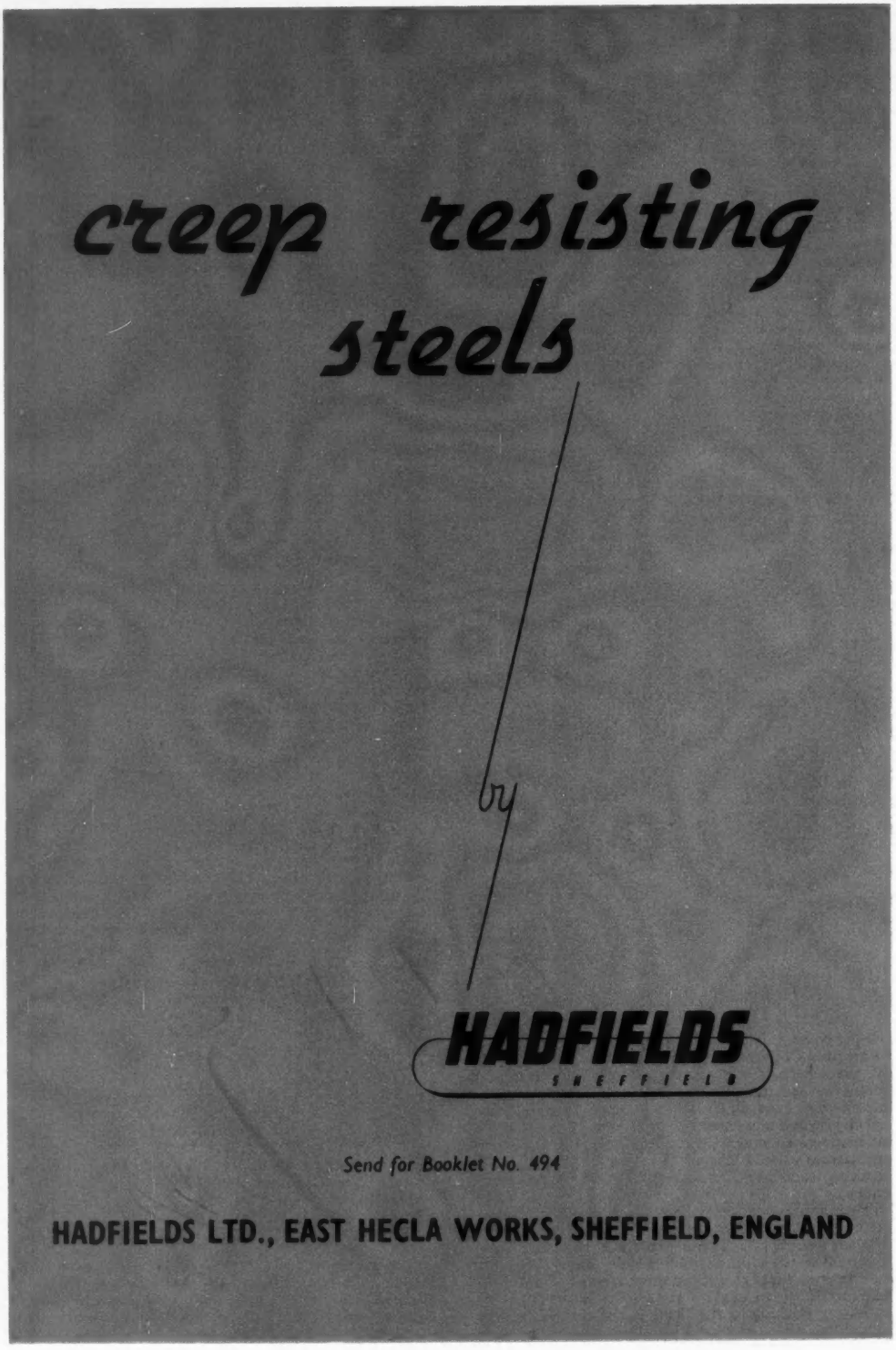
ALLOYS which are protected against corrosion by a dense skin of oxide, and thus may serve as heat-resistant constructional materials, sometimes show a strongly accelerated oxidation when brought into contact with foreign substances, especially foreign oxides. With a view to accounting for this phenomenon, the oxidation of a series of metals and alloys, including those with copper, iron and silver as base, has been investigated for the case where these are brought into contact with molybdenum oxide (MoO_3 in powder form). The degree of oxidation (" penetration depth ") was determined by measuring the breaking strength of wires drawn from the respective material and heated in air with and without contact with MoO_3. When the oxidation is thus determined as a function of temperature, a curve is obtained showing one or more discontinuities where the oxidation is suddenly accelerated. These discontinuities appear to lie at the eutectic temperatures of the systems of the respective oxides (lowest temperatures at which the formation of liquid occurs). From this it can be concluded that the accelerated oxidation is due to formation of liquid in the protective oxide skin of the alloy. The accelerating effect of the liquid upon oxidation is readily understood, and from the relation that has been found it is also possible to explain many peculiarities in the temperature- and time-dependency of the oxidation. In some cases, oxides of the basic metal not essentially belonging to the protecting skin, such as Cu_2O in the case of aluminium bronze, may considerably contribute towards a lowering of the eutectic temperature. Sometimes in the presence of MoO_3 perceptible oxidation already takes place below the lowest eutectic temperature. This is accounted for by the absorption of molybdenum ions in the crystal lattice of the oxide skin and the accompanying greater freedom of movement of electrons and metal or oxygen ions. A third way in which MoO_3 may promote oxidation is found in the case of silver. Silver, as a precious metal, is not oxidizable above 150° C in air of normal pressure, but in the presence of MoO_3 double oxides may be formed, making it possible for oxidation to take place at much higher temperatures; then again, melting phenomena in the oxide skin make their influence felt.

THERMODYNAMICS

On the Evaporation Velocity of a Liquid Droplet in a High-Temperature Gas

By Y. TANASAWA and K. KOBAYASI. (From *The Technology Reports of the Tohoku University, Japan*, Vol. 14, No. 2, pp. 55-67, 8 illustrations.)

How many seconds does it take a spray to evaporate when injected into a hot gas? This problem is related not only to combustion in diesel engines and gas turbines, but also to combustion in petrol engines, where it is very useful to find the rate of vaporisation of fuel droplets which leave the carburetter and are just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about to be ignited in the engine cylinder. Moreover, it is an important problem to the chemical industries using spray dryers.

Researches have in the past been based on experimental measurements or on calculations in combination with experiments in special cases, and it is therefore impossible to deduce any generally applicable results from them. The measurements of the rate of evaporation of a liquid droplet are generally difficult, as partial pressure distribution is an important factor which cannot be measured by present experimental technique. We therefore have to allow for certain errors and must expect great difficulty in arriving at more generally applicable results. Because of this fact, theoretical treatments have often been tried, but unfortunately no valuable solution has yet been found.

In the present paper, as a fundamental case of theoretical treatment, an attempt is made to investigate the rate of evaporation and the time required for evaporation when only one droplet is injected into a high temperature gas.

WELDING

Aircomatic Welding of Nickel-Clad and Stainless-Clad Steels

By T. T. WATSON and R. R. ROTHERMEL. (From *The Welding Journal, U.S.A.*, Vol. 30, No. 3, March, 1951, pp. 166s-122s, 10 illustrations.)

NICKEL-CLAD and stainless-clad steels can be welded successfully by the Aircomatic process, as evidenced by the excellent mechanical properties exhibited by the welds in bend tests. The Aircomatic process is superior to manual welding of clad steels in that fewer weld passes are required and the joint preparation is less expensive.

Procedures were developed for making butt welds on clad plates of $\frac{3}{8}$ in. gauge or less by the Aircomatic process. One of these procedures consists in making a complete weld by depositing a single bead of alloy weld from the backing steel side of the clad plate. The other consisted of depositing an initial alloy weld from the backing steel side and completing the weld with one or more light beads from the clad side.

To maintain the desired ductility in welding stainless-clad steels, it was found necessary to use 25 Cr-20 Ni welding wire for all welds deposited from the backing steel side. The ductility of welds made on stainless-clad steel plates (10 per cent cladding) was considerably improved by stress-relieving.

Clad plates greater than $\frac{3}{8}$ in. in thickness were welded manually from the backing steel side with mild steel electrodes, while the Aircomatic process was used for the clad side. Good mechanical properties were obtained with this procedure. Further experiments are necessary to determine the maximum plate thickness that can be successfully welded with the Aircomatic process.

In welding by the Aircomatic process, several factors are critical in obtaining sound welds of the desired penetration. The fit-up of plates must be such that a root gap of about $\frac{1}{32}$ in. is maintained, otherwise depth of penetration will not be controllable. The surfaces of the plates to be welded must be free of scale and rust in the vicinity of the joint, to prevent porosity and arc instability.

Joining Cast Iron

By C. O. BURGESS. (From *Machine Design, U.S.A.*, Vol. 23, No. 3, March, 1950, pp. 129-131, 5 illustrations.)

GREY iron and grey iron castings can be successfully welded if certain simple but essential practices are employed. Such a statement would appear obvious if, for many years, it had not been believed that there were no suitable methods of joining grey iron castings, and the use of castings in fabricated assemblies had not even been considered. As a result of this scepticism grey iron was replaced in certain types of construction by other materials, which, although less suited to the application from other points of view, could be easily welded.

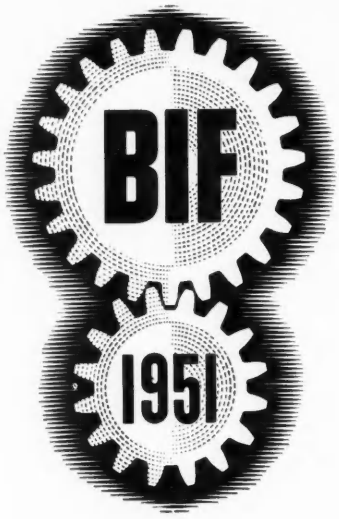
There are, however, two main cases in which joining of castings by welding may be desirable: (1) If the requirements of the part necessitate the use of another metal in integral combination with grey iron, and (2) if the design of the structure is extremly intricate, so that casting in one piece presents problems to the foundryman which cannot be solved economically even by the use of good foundry practice. It should be emphasised that such cases as the latter are not common but do exist. There is no question that castings of extreme intricacy can be produced by the foundry with consistency by the use of proper gating, coring and risering. However, the cost of cleaning-out inaccessible cored cavities, etc., occasionally outweighs the inherent advantages of integral cast construction.

Recent progress in joining technique has demonstrated that, with proper precautions, grey iron castings can be satisfactorily welded or joined to other metals and to other castings. It is true that these approved welding procedures generally require skill, special rods or preheating, and to that degree may be more expensive to apply to grey iron than to mild steel. Nevertheless, ultimate economy frequently results from the use of an inexpensive base material and, more important, from the improvement of the final product resulting from the ability of the designer freely to employ the valuable qualities of grey iron wherever they are needed.

The Smitsvonk Low-Tension Capacity Ignition

(*Concluded from page 113*)

7 kg/cm² (100 psi). All the chambers were provided with glass observation windows. Comparative tests were made with a Smitsvonk surface-discharge plug and a standard high-tension type plug, which were provided with insulators of the same length and tested simultaneously in the apparatus. Both sparking plugs operated at a sparking frequency of 500 sparks per minute. The air pressure in the rear chambers, initially equal to 760 mm Hg, corresponding to sea-level conditions, was gradually reduced, in order to determine the pressures at which the sparking plugs would cease to function normally. At 229 mm Hg, corresponding to an altitude of about 9,000 metres (29,500 ft), glow discharges appeared over the insulator of the high-tension sparking plug; the sparks in its pressurised front chamber became erratic and ceased completely when the pressure in the rear chamber was further reduced. The Smitsvonk low-tension spark continued functioning normally, and it was only at a pressure of 40 mm Hg, representing an altitude of approximately 20,000 metres (65,600 ft), that the first glow discharges were observed along the sparking plug insulator. In the pressurised chamber, however, the sparking still appeared to be normal. As the vacuum pump used was unable to reduce the pressure in the rear chamber any further, the test was discontinued at this stage. The test indicated that for high-altitude operation, other components would first reach critical conditions at an earlier stage, and showed the advantages of the low-tension sparking plug over the high-tension plug operating under similar conditions.

APRIL 30 

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ENGINEERING AT CASTLE BROMWICH

BRITISH INDUSTRIES FAIR 1951

April 30—May 11

The 30th British Industries Fair to be held from April 30th to May 11th simultaneously at Olympia and Earls Court in London and at Castle Bromwich, Birmingham, will coincide with the Festival of Britain celebrating the centenary of the Great Exhibition of 1851.

This year's British Industries Fair will surpass the previous Fairs both in size and significance, and it will demonstrate once more the increasing capacity and technical predominance of British industry.

Although certain industries which are having their own Exhibitions, such as machine tools, ship-building, motor cars, will not be represented at the B.I.F., the displays will provide nevertheless a most impressive evidence of British technical and industrial progress.

The Engineering and Hardware sections will be housed, as in previous years, at Castle Bromwich, Birmingham. Other sections, displaying scientific instruments, chemicals, optical and photographic goods, radios, office appliances, plastics, textiles and domestic appliances, will be seen at Olympia and Earls Court in London.

In the limited space which we can devote to the B.I.F., we are only able briefly to describe a small number of exhibits. Some further exhibits will be reviewed in the next issue of our journal.

It is hoped that an even larger number of home and overseas engineers will visit the Exhibition than in the record post-war years to view the latest developments in materials and finished products.

For the first B.I.F. for many years, furnace equipment will not be featured on **Birlec Limited's** stand. Furnace friends will be invited to Birlec's Research Department less than three miles from the Fair grounds.

Emphasis in 1951 will be on Birlec-Lectrodryer equipment for the controlled dehydration of gases, including air, and certain organic liquids. Lectrodryers employ Activated Alumina as the drying agent—a hard, granular, porous material with the ability of taking up, or absorbing, moisture on its surface area and giving it up again when heated. By using two beds of Alumina, therefore,—one adsorbing and the other being reactivated—continuous drying takes place, the functions of the two beds being alternated, either manually or automatically, on a predetermined cycle. Alumina does not deteriorate by reactivation and has, consequently, a practically indefinite life.

The need for dry air or gas arises in many industries of which the chemical, pharmaceutical, metallurgical, confectionery, refrigeration and general engineering are the most important. The uses for Lectrodryers fall broadly into two classes—(1) the humidity control of large enclosed spaces, such as storage or work rooms, and (2) the drying of gases for processes such as furnace atmosphere control, instrument operation, etc. Units of each type will be exhibited on the Birlec stand.

The air conditioning plant is a model CHG Birlec-Lectrodryer ; it supplies continuously over 20,000 cu. ft. of dehumidified air per hour. This model is electrically reactivated although similar units incorporate steam—or gas-heated coils to extract moisture from the alumina. Larger units of this type handle up to 900,000 cfh.

The process gas dryer is a model BWC 1500 Birlec-Lectrodryer ; this unit, already sold, will be installed at an oil refinery abroad for maintaining a supply of dry air to air-operated instruments. Capacity of this unit is 1200 cu. ft. per hour. The alumina is reactivated by steam and the outlet gas can be dried to very low moisture content.

The Lab Lectrodryer will be shown as a minor display ; this small compact unit has found many uses in research, pilot or small-scale process work. Photographic displays and diagrams will demonstrate the more important Lectrodryer applications throughout industry.

The 1951 B.I.F. will be the first exhibition at which the Lectrodryer will have been shown on any scale. It is anticipated that great interest will be aroused in many industries at present troubled by humid weather conditions and moisture-laden compressed air or process gas.

British Insulated Callender's Cables Ltd. will be displaying a wide range of electrical products. Exhibits will include High-Voltage Cables, Mass Impregnated Non-draining Cables, the Claw-type Cable Cleating System and the Industrial Wiring System. Also, Power Capacitors, Electric Resistance Welding Machines, and a demonstration model of the Wire Rope Parting Machine.

The Company's latest designs of Impregnated Pressure type cables, including single—and three-core types for voltages between 33kV and 275kV will be displayed. Of particular interest will be the featuring of the World's largest cable—a 132kV, 3-core I.P. cable of over 5 inches diameter.

M.I.N.D. Cables on show have been developed and patented by B.I.C.C. They are of normal paper-insulated, lead—or aluminium—sheathed construction but include a special impregnating compound that will not migrate, even in vertical runs at sustained maximum working temperatures. They are particularly suitable, therefore, for installations in mine shafts, lift shafts, for rising mains in office blocks and flats, etc. They can be supplied with any type of serving or armouring, and can be used indoors or out-of-doors, or under the ground. This type of cable is particularly advantageous for high-ambient temperature situations overseas and is available for service up to 11,000 volts—to British or other recognised standards. Current ratings are the same as for cables of the ordinary fully-impregnated type.

B.I.C.C. Claw-type Cable Cleats have been developed to satisfy the need for a universal assembly which can be easily built-up and modified—on site—to suit any arrangement or re-arrangement of cables. The cleats are suitable for all types of cable sheathed with lead or aluminium (bare, served or armoured) and can be installed in any normal indoor or outdoor situation. They can be used either singly or in groups, and are equally suitable for mounting on walls or steelwork for both horizontal and vertical runs.

B.I.C.C. " domestic " and " farm " wiring systems are already available for many applications, the former being suitable for houses and other small premises—even where a degree of dampness or corrosive influence may be present—and the latter being suitable for the more severe forms of dampness and corrosion associated with certain types of farm buildings. For many industrial applications, however, an even higher degree of resistance to corrosion is necessary and this has been fully met by the new All-Insulated Industrial Wiring System which will be featured.

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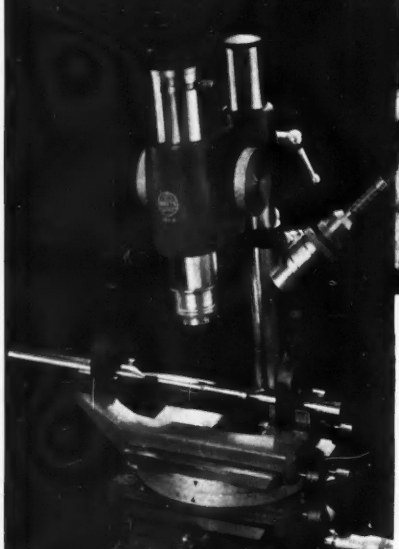

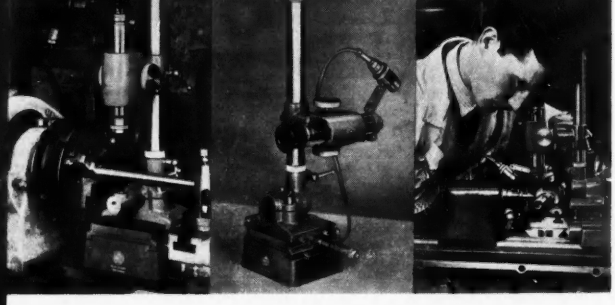

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Machines to be shown and demonstrated include the ML 75 Flash Butt Welding Machine : a general purpose machine of 60 kVA capacity of the hand lever operated type. The transformer primary winding is tapped to give eight secondary voltages suitable for welding mild steel or tool steel in the range of 0·1 sq. inch to 0·75 sq. inch ; the 161 A Spot Welding Machine : a modernised version of the B.I.C.C. M 194 machine. It is of the pedal-operated rocking head type, designed for general work in the sheet metal and light fabrication industries. The transformer is rated at 20 kVA and the machine welds a maximum added thickness of mild steel of $\frac{7}{16}$ inch. It will also weld a variety of alloy steels and non-ferrous metals, including brass and aluminium, up to $\frac{1}{8}$ inch added thickness ; the MS 101 C Welding Machine : specially designed for butt-welding fine wire—either ferrous or non-ferrous. It is arranged for bench mounting and can be supplied for steel wires from 0·0108 inch diameter to 0·056 inch diameter, or alternatively, for copper wires from 0·0108 inch diameter to 0·048 inch diameter. A special feature of the machine is ease of operation, a single finger-operated lever both releasing the moving arm and closing the switch to complete the primary circuit of the welding transformer ; the M 196 A Spot Welding Machine : a light duty, pedal-operated, bench-mounted machine of the rocking-head type, suitable for a wide variety of light and delicate work, for example :— electronic valve assembly and orthodental work. The transformer has a nominal rating of 2·5 kVA ; a tapping switch selects any of five secondary voltages suitable for the normal range of work of the machine ; the BM 1 Fine Wire Brazing Machine : a small machine for electrically heating the ends of fine copper wires for silver-soldering ; the MS 301 Welding Machine : a new type of wire butt-welding machine with very simple control.

The RP Wire Rope Parting Machine is the first of its kind to be marketed. A scale model will be used to demonstrate the parting of wire ropes in such a manner that the ends are sealed and left in a tapered form—thereby greatly facilitating threading through blocks or pulleys and subsequent clamping.

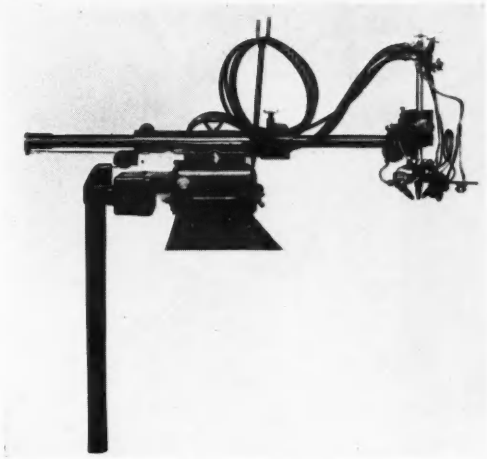
The British Oxygen Co. Ltd., will exhibit light equipment including the DH. and CH. general purpose Blowpipes, the Nos. 1 and 2 Cutogen Hand Cutters and the Cutogen No. 4 Combined Welding and Hand Cutting Blowpipe. In addition to this range of popular general purpose equipment, Oxy-Acetylene Lead Burning outfits with the Model ' O ' light duty blowpipe will be shown. This blowpipe is also suitable for welding small sections (zinc base die castings, etc.).

In machine cutting, a feature of special interest will be the P.E.P. (Plate Edge Preparation) Machine fitted with the MULTIFLOAT ATTACHMENT (illustrated here). This combination which is drawing the interest of shipyards and constructors throughout the United Kingdom is used for preparing the edges of ships' plates, etc. for welding by the simultaneous sizing and cutting of bevels and nose on the plate edges. With four machines running on a suitable track all four sides of the plate can be cut at the same time. With the Multifloat type of machine, curves can also be cut on one or more of the plate edges whilst the other cuts are in progress. The correct edge form double or single bevel, etc. is maintained during the cutting of the curve.

Other cutting machines on view and to be demonstrated will be the 55 in. and 36 in. U.C.M. (Universal Cutting Machine) and the P.S.L. (Portable Straight Line) Cutting Machine.

Portable Welding Outfits, consisting of Blowpipes, Regulators and Oxygen and Acetylene Cylinders mounted on lightweight trolleys will be displayed.

Rods and Fluxes for welding, building up and hardfacing will be available for most ferrous and non-ferrous metals and the majority of alloys in both classes.



Equipment obtainable under the B.O.C. Service Exchange System will be on view and will include Regulators, Gauges, Blowpipes, etc.

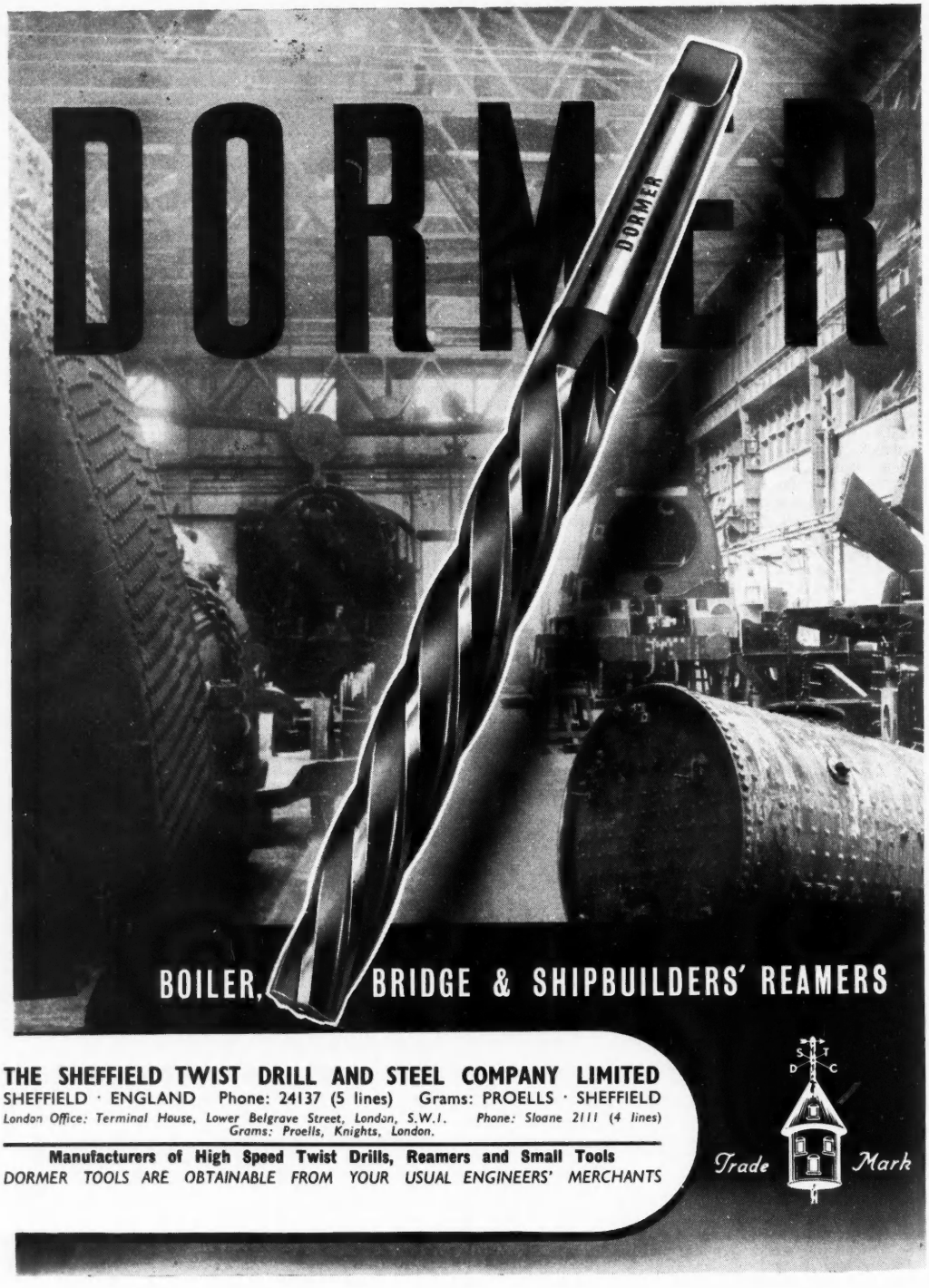
The Argonarc Process will be featured together with the latest additional equipment which includes amongst other things a Water Cooled Shield on the Mark III Torch for continuous heavy duty work. The Mark III Water Cooled Torch and the C.P.U. 300Q and M.G.300 Power Units will be used for demonstration purposes. Demonstrations will be given on aluminium alloys, magnesium and its alloys, copper, stainless steel and heat resistant nickel alloys. The A.W.M.3 Automatic Argonarc Machine will also be shown.

Free technical literature covering the many processes to which the equipment is applicable will be available.

Against a background of heavy electrical plant, augmented by dioramas, photographic displays, and a scale model of a hydro-electric station, a comprehensive selection of B.T.H. products will be demonstrated at the stand of **The British Thomson-Houston Co., Ltd.** These exhibits range in size from a 12-ton, 10-ft diameter helical gearwheel of the highest accuracy for marine propulsion, to such smaller items as a very high-speed electronic counter. The exhibits will include power station and industrial switchgear ; a three-phase high-voltage contactor unit particularly suitable for such applications as the control of stator circuits of large induction motors driving mine hoists ; electric motors from fractional horsepower sizes up to 50 hp ; part of the B.T.H. electronic control equipment for the " Daily Mirror " newspaper printing machines ; industrial electric control gear, including " Stacreep " crane control ; thrustors ; suds pumps ; industrial electric heaters ; " Fabroil " pinions ; and the latest developments in Mazda lamps and lighting equipment. Many of these exhibits will be operating, and a halogen vapour leak detector, a gauss meter for determining the strength of magnetic fields in very small air gaps, and a fluorescent lamp and circuit component tester, will also be available for demonstration to interested visitors.

Fibreglass Limited will be featuring the insulation of domestic equipment with glass fibres. Such insulation is increasing the efficiency and reducing the bulk of refrigerators and cookers.

A convincing demonstration of this efficiency is planned on the Fibreglass stand. Some unbaked scones will be placed in a hot oven together with several cartons of ice-cream wrapped in " Fibreglass " insulation. About 15 minutes later the scones will be taken out baked and the ice-cream removed still frozen hard.



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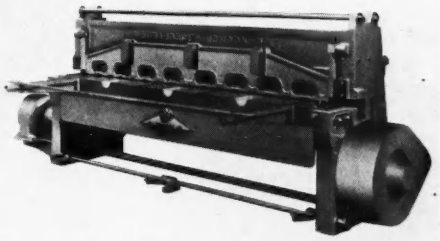
F. J. Edwards Ltd. will display a representative selection of their wide range of tools and machinery. These will include six new machines, four of which are of particular interest to the sheet metal working and allied industries, whilst a new inclinable power press and a bar cropping machine should prove attractive to those concerned with press work and structural engineering, respectively.



The Besco Production Guillotine Shearing Machine, Type 96-10, shown in the illustration, has a capacity of 69 in. by $\frac{1}{8}$ in. for mild steel. Constructed of heavy cast steel ribbed sections, rigidly bolted and braced to eliminate deflection, the machine is of the undercrank, open end type, geared, and driven through a finely balanced fly-wheel, by multi vee belts from a self contained 8 hp motor at 1,500 rpm, giving 65 strokes per minute. The fly-wheel and all gearing has a good ground clearance and no pits are necessary. With the blades ground to a special angle, plastic sheet, mica, cardboard, asbestos, rubber and similar material can be cut cleanly and accurately.

Another machine newly introduced is the Besco Production Treadle Operated Guillotine, with a rated capacity of 36 in. × 48 in. wide, by 16g for mild steel. This is of streamlined steel plate construction and is suitable for cutting a wide variety of materials, such as mild and stainless steel, copper, brass, aluminium and duralumin. Other materials, including rubber, fibre, mica, and cardboard can be sheared with a clean straight edge if the top blade is ground to a more acute angle.

The modern design of the Besco Production $\frac{1}{8}$ in. capacity Circling Shear incorporates a number of features of calculated assistance to the precision production and rapid repetition of sheet metal work, in which the cutting of discs and rings to fine limits, without undue preparation or wastage is a first essential. Sheet metal circles from 9 in. to 63½ in. in diameter by $\frac{1}{8}$ in. thick mild steel can be cut from square blanks, the largest size which may be inserted without trimming being 90 in. across the corners.

The Besco Production Inclinable Power Press, Model B.A. Mark 11, has a range of three sizes with the stroke adjustable throughout the range from the normal $\frac{3}{8}$ in. to $1\frac{7}{8}$ in. in the smallest, to $2\frac{3}{8}$ in. and $2\frac{3}{4}$ in. in the two larger sizes respectively, with pressure exerted varying between 10, 18, and 28 tons, according to size.

The vital importance at the present time of equipment for the generation, transmission and distribution of electrical power has led **The General Electric Co., Ltd.,** to devote the whole of its stand to its manufacturing resources for this class of work. Bearing in mind that the G.E.C. is in a position to supply the whole of the electrical equipment and much of the mechanical plant for a modern power station, many of its products, such as transformers, outdoor switchgear, overhead transmission lines and cables had to be omitted.

The stand is divided into two parts, one of which is devoted to turbo-alternators and coal handling plant, and the other to certain designs of indoor switchgear selected from the wide range produced by the Company. Scale models of typical 30 MW and 60 MW turbo-alternators with their associated auxiliaries provide visual comparison of the space required for sets of these standard B.E.A. ratings. Two wheels of a 60 MW turbine designed to work at 900 psi, 900° F are on view. The one is the first high pressure wheel which has a mean diameter of 25·88 inches and a blade height of 1·92 inches, while the other is the last wheel of the machine and has a mean diameter of 75 inches, and a blade height of 20 inches. In addition there is a display of turbine blading, including high pressure and diaphragm nozzles.

A working model of a Fraser and Chalmers Marshall Side Discharging Wagon Tippler (Fig. 1) which for demonstration purposes, is shown operating in a closed circuit with a system of Sherwen Electromagnetically-operated Vibrating Feeders, completes this part of the stand.

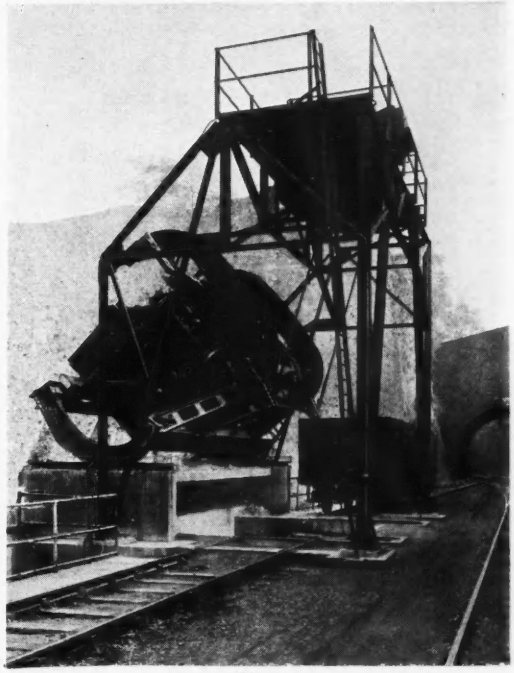


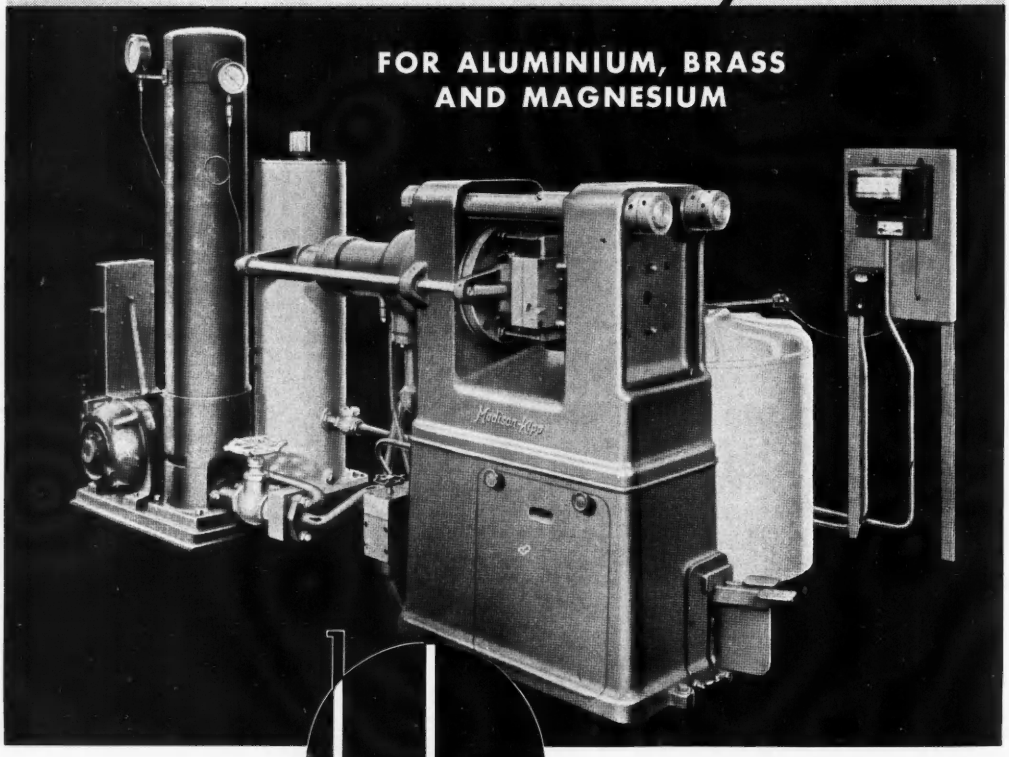
Fig. 1.

Dominating the whole of the stand is a 33 kV, 1500 MVA duplicate busbar, heavy duty metalclad unit for main power station service. This is the largest unit in this range of switchgear which covers equipment for voltages from 6·6 kV to 33 kV with breaking capacities up to 1500 MVA. The design provides for complete phase and cable segregation and complies fully with the official recommendations for avoiding fire risk.

For substation service, two 11 kV metalclad units with breaking capacities of 350 MVA and 150 MVA (see Fig. 2) respectively, are being shown. Both designs adopt a form of construction in which the circuit breaker is mounted on a withdrawable carriage. Many features such as vertical isolation, fabricated steel construction, accessibility and complete segregation of the ancillary equipment from the high voltage side are common to both designs which are similar in their external appearance. The major difference is in the

NEW DESIGN — NEW FEATURES — NEW RESULTS

A Patented Die Casting Process



MADISON-KIPP hi-high PRESSURE MACHINES

Illustrated above is a modern, compact and complete die casting department for making dense castings of pre-determined analysis. There are two machine sizes in the new "Ladle Type" 400 Series for die casting metals that melt at high temperatures--Brass, Aluminium, and Magnesium. For Zinc, Lead and Tin alloys which melt at comparatively low temperatures, there are other models of "Gooseneck Type" machines in all sizes. The Coulthard Die Casting Service is complete. It includes die designs, dies, machines, and die castings in all die casting alloys. You are invited to send blue prints or samples for a complete analysis or to come to Carlisle to see for yourself.

WILLIAM COULTHARD & CO. LTD.

ENGINEERING DIVISION · DURRANHILL ROAD · CARLISLE

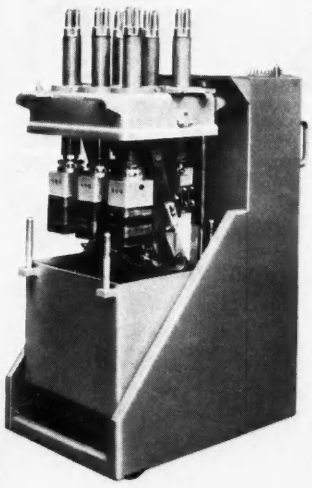


Fig. 2.

design of the circuit breaker itself. In the larger units, a double break is employed whereas in the 150 MVA switchgear the circuit breaker is of the single break type.

The Company's range of air-break switchgear, is finding increasing application in power stations for controlling auxiliaries, and both medium voltage and 3·3 kV units are being demonstrated. The medium voltage switchgear is suitable for voltages up to 660 volts and breaking capacities of 15, 25 and 30 MVA. Units for current ratings up to 800 amp. are available either in single tier form or in double tier form, with its resulting valuable saving in space. The upper and lower compartments may each house a circuit breaker (Fig. 3). Alternatively, either or both compartments may accommodate fused switches, contactors, isolators, etc., for the control of circuits which do not demand a circuit breaker. For heavier current ratings, i.e. exceeding 800 amps. and up to 2,000 amps. a single tier cubicle is used. In all cases the circuit breakers are mounted on carriages and may be completely withdrawn from the cubicle.

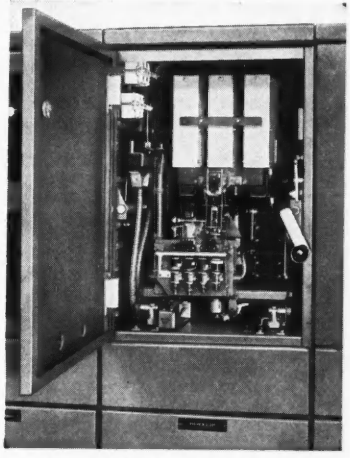


Fig. 3.

Externally, the 3·3 kV unit is similar in many respects to its medium voltage counterpart. It is designed for breaking capacities of 100 and 150 MVA and in current ratings of 800, 1,200 and 2,000 amps. The circuit breakers can be arranged for solenoid spring or manual operation, emergency hand-operation being provided in all cases. In both 3·3 kV and medium voltage equipments withdrawal of the circuit breaker on its carriage enables inspection and maintenance to be carried out in perfect safety.

A comprehensive range of components for remote control boards has been standardised and includes such items as key synchronising switches, combined circuit breaker control switches and semaphores, semaphore indicators, motor control switches, ammeter switches and the like. The designs have the advantage of giving uniformity of appearance combined with simplicity of fitting. In every case only one hole has to be drilled in the panel, each component being secured in place by a clamping ring. Typical control panels serve to illustrate the pleasing and uniform appearance resulting from the use of these components.

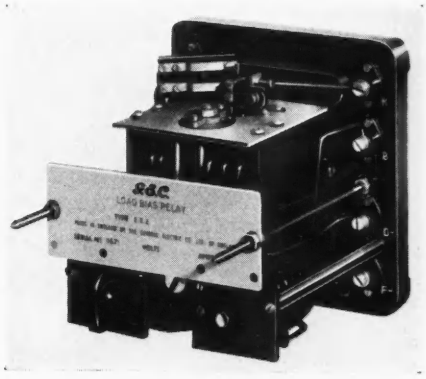


Fig. 4.

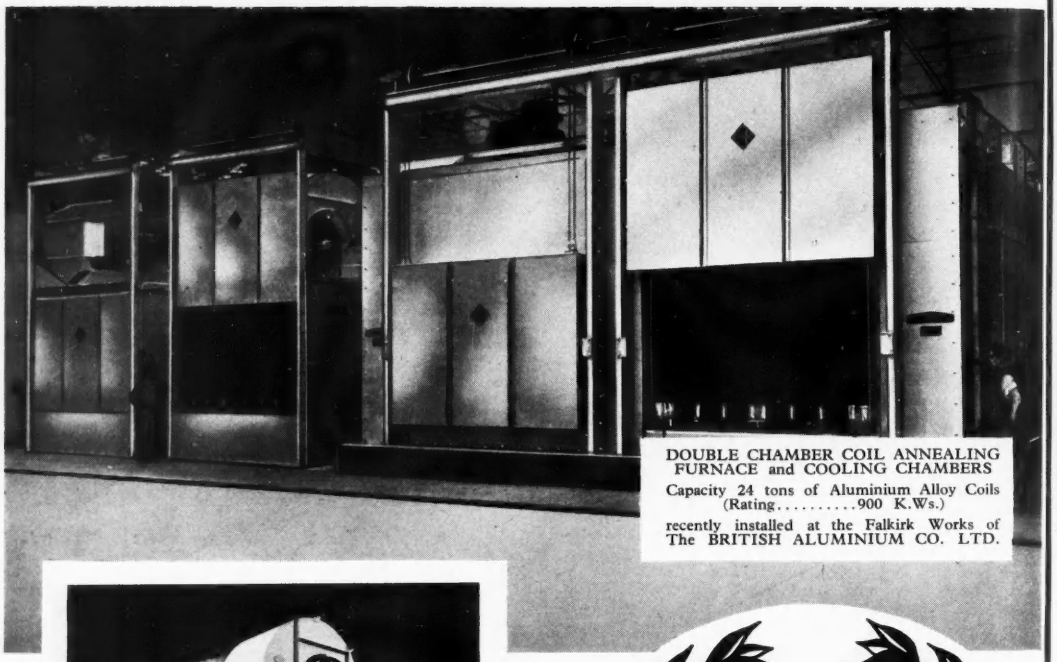
Modern protective relays, one of which is shown in Fig. 4, are also in evidence and the display includes a relay panel arranged for demonstrating the operation of various relays selected from the Company's comprehensive range. Finally surge diverters for rural service complete the exhibits. They are suitable for systems from 2·2 kV to 33 kV normal voltage and consist of spark-gaps and non-linear resistors so designed that the surge diverter can discharge electrical surges harmlessly to earth.

The Hymatic Engineering Co., Ltd. will show for the first time a new agricultural compressor, specially designed for direct mounting on the popular makes of tractors. For the small capital outlay involved, it provides a self-contained, mobile source of cheap power for such jobs as paint or insecticide spraying, tyre inflation and for operating hedgecutters, pruners and other pneumatic tools. Driven by a belt from the tractor pulley, this twin-cylinder, air-cooled compressor displaces 13-14 cfm at working pressures of up to 100 psi. Pulley diameters are so arranged that the tractor runs at a moderate speed, thus conserving fuel and increasing efficiency. The complete unit can be fitted in less than half an hour.

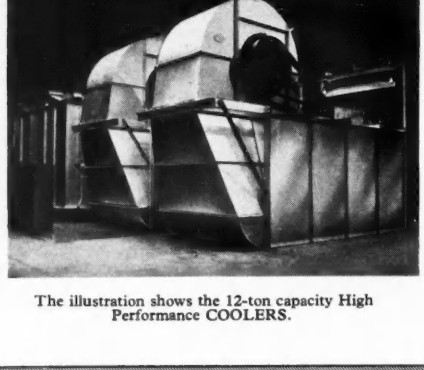
A representative range of electric or petrol driven static, mobile and portable Hymatic compressors will form the principal feature of the display. Among them will be robust receiver-mounted sets of the static type suitable for use in garages, workshops and small factories, etc.; medium-powered mobile models widely employed in the building and allied industries; smaller all-purpose mobile sets, used in building, agriculture and factory maintenance, and a self-contained portable unit for taking compressed air power to sites inaccessible to the standard types.

THE SYMBOL OF PROGRESSIVE DESIGN

Experience improves Heat Treatment Efficiency



DOUBLE CHAMBER COIL ANNEALING FURNACE and COOLING CHAMBERS
Capacity 24 tons of Aluminium Alloy Coils
(Rating.....900 K.Ws.)
recently installed at the Falkirk Works of
The BRITISH ALUMINIUM CO. LTD.



The illustration shows the 12-ton capacity High Performance COOLERS.

Precise
Forced Convection
giving greater turbulence, increased rate of heat transfer, and finer control of temperature.

Rapid Door Operation
5 seconds — No Shock

McDONALD
FURNACES LIMITED

DAWLEY BROOK · KINGSWINFORD · STAFFS
Telephone : Kingswinford 3328
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The recently introduced Hymatic DP6, a small electrically-driven diaphragm-type compressor was specially designed to provide air uncontaminated by oil vapour or other impurities for food processing, raising liquids and for special applications in medical and industrial laboratories. No lubrication whatever is required—the bearings being grease-packed—and very little maintenance.

Outstanding among the variety of ancillary equipment to be shown is the Hymatic Air Rectifier, type R50, a device which ensures that all traces of oil and water vapour are removed from the air supply and which provides an accurate and easily adjusted control of the pressure. These rectifiers can be supplied separately or fitted to Hymatic Pressure Feed Containers which will also be displayed and which are now regarded as indispensable for large area spray painting. Suitable spray guns for use with this equipment will also be featured.

Four examples from a comprehensive series of air hammers will be on show. The first two are pistol-grip type models, the PH107 consuming 3 cfm of air and delivering up to 6,000 blows per minute, and the PH108, a more powerful version, consuming 6 cfm and delivering 5,000 blows per minute. The PH113 and 114 are heavy duty types with spade-grip handles designed to reduce operator fatigue when used for long periods.

Prominent among the exhibits on the stand of **The Morgan Crucible Co., Ltd.** will be a working 8-unit " Carbinert " cascade cooler. For cooling corrosive liquids this cooler combines the advantages of economy in first cost and space requirements. The design also allows for ease of replacement of spare units. " Carbinert " can be machined to very close tolerances and can be utilized for many applications in chemical engineering where its distinctive properties are of inestimable value. For heating corrosive liquids a variety of " Carbinert " tank heaters are available.

CARBLOX chemical tank linings combine high chemical inertness with excellent resistance to abrasion.

" Carblox " corrugated hearth blocks and standard shapes for blast furnaces will also be displayed. This material has crushing strength, and resistance to abrasion which is appreciably higher than that of the firebricks normally used for blast furnace linings.

An extremely wide and varied range of anti-friction engineering parts manufactured from " Morganite " materials will demonstrate both electrical and mechanical applications.

The unique properties of " Morganite " Carbon include :—Self-lubrication ; wide range of resistance to chemical attack ; low thermal expansion ; good mechanical strength at high temperatures ; high resistance to thermal shock ; good thermal conductivity ; not wetted by molten metals, slags, or glass ; good electrical conductivity.

Among " Morganite " Carbon components exhibited will be :—Crane Current Collectors ; Trolley Bus Collector inserts ; Seals ; Valves for water and petrol meters ; Gland rings for turbines and compressors ; Piston rings ; Welding rods ; Furnace parts and Metallurgical Tubes and Boats ; Formers, Dies, Plates, etc. for the Glass Industry ; and Bearings.

" Morganite " Carbon bearings work efficiently under arduous conditions—in corrosive chemical fumes —in temperatures and under conditions which preclude the use of grease or oil lubricants. They operate satisfactorily in conditions ranging from below freezing point up to 500° C. Under wet conditions they can sustain high load and speeds in fumes such as petrol, paraffin, trichlorethylene, etc., where ordinary bearing metals could not function.

" Morganite " Carbon Seals are chemically inert and are recommended for use in petrol, paraffin, water, solvents, alkalis and in all but the strongly oxidizing reagents.

The range of refractory brick shown will include a selection of grades for use in heat treatment furnaces, boiler settings, oil stills, steel ladles, etc. made by **The Douglas Firebrick Co., Ltd.,** Dalry, Ayrshire.

" Reservoil " oil-retaining bearings consist of a strong porous bronze or, for heavier loads, porous iron material impregnated with lubricating oil. A film of this oil is picked up by the rotating shaft, the oil being continuously fed to the bearing surface by circulation through the pores of the bearing. Thus is maintained a most efficient and economical system of lubrication, in which a small quantity of oil is rendered quite adequate by being used again and again, none being left free to run to waste or cause oil spoilage.

The bearings are especially recommended for domestic and other equipment likely to remain unserviced, and for industrial equipment fitted with a large number of bearing points. Fitting is a simple and quick operation readily lending itself to repetition. Plastic or die-cast housings can be used. In manufacturing die-cast equipment requiring accurately fitted bearings it is an economy to die-cast the alloy round dry " Reservoil " bearings and afterwards impregnate them with oil. The usual P.V. (pressure in psi × surface velocity in fpm) of " Reservoil " bearings is 25,000. There are, however, a number of industrial applications where the bearings sustain for long periods a P.V. as high as 70,000 often without supplementary lubrication.

In addition to the widely known and used " Salamander " and " Salamander " Super Crucibles, exhibits will include " Salamander " plumbago launders, muffles, knock-off riser plates, moulds, stoppers and nozzles, tundishes, stirrers, skimmers and bricks and shapes for steel ladle and other linings.

" Morganite " Brushes displayed will include types of brushes as used all over the world, on all patterns of industrial and fractional electrical machines.

" Morganite " Brush Holders of all types will be on show, together with Brush Bedding Stones and Heavy Duty Resistors. An exhibit of interest will be the showing, for the first time at the B.I.F., of the Metal-Carbon Contact Tip for controller and contracter applications.

" Morganite " Resistors Limited, subsidiary of The Morgan Crucible Co., Ltd., are now concentrating on the manufacture of carbon resistors, potentiometers, volume controls, and interference suppressors at their new factory on the Bede Trading Estate, at Jarrow. Their well known range of potentiometers, and tropical controls has recently been extended by the production of the Type " A " potentiometer which can be supplied either with or without switch. The switch, of an improved design, has successfully passed the stringent tests imposed by the leading Continental Electricity Authorities, including Sweden, Norway, Denmark, Finland, Switzerland, etc.

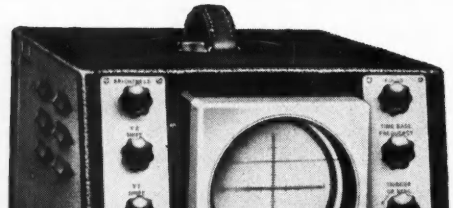
The range of fixed type carbon resistors has been simplified and concentrated into two types, " R " of 1 watt and " T " for all ½ and ¼ watt applications. These resistors, both of the axial wire types, can be supplied in the full range of preferred values, with tolerances of 20, 10, or 5%.

For interference suppression of automobile ignition systems, this Company offers Type C.1 for fitting into the H.T. cable lead, Type B.1 for fixing to plugs, screw on terminal and Type B.3 for plug fitting with a push on terminal. In addition a new Type D.1 for fitting into the central socket of distributors is likely to be available shortly. Resistance values of 5,000, 10,000 and 15,000 ohms can be supplied.

English Steel Corporation Ltd. will show for the first time in this country a six-throw Diesel Engine Crankshaft, press-forged by the R.R. Continuous Grain-flow process, sole British rights for which have been acquired by this Company.

(*Continued on page* 139)

THE COSSOR DOUBLE BEAM OSCILLOGRAPHS



Can this Instrument solve a problem for you?

Here are some details of Model 1049 as illustrated: The Double Beam Tube presents two simultaneous independent traces over the full diameter of a 90 mm. screen, and provision is made for the measurement of both input voltage and time upon the calibrated dials of the instrument. The Oscillograph is particularly suitable for obtaining permanent photographic records using the Cossor Model 1428 Camera for which a Motor Drive Attachment Model 1429 is available.

Widely different industries are daily finding new uses for the COSSOR Double Beam Oscillograph. Sometimes it provides the answer to an industrial problem of long standing. The tracing and measurement of noise, strain and vibration are typical everyday applications of this versatile instrument which is already helping engineers in industries as far apart as brewing and the manufacture of jet engines. Call on our technical advisory staff if you have a problem. They will quickly let you know whether the Oscillograph can help you.

COSSOR

Double Beam OSCILLOGRAPHS

Please address enquiries to:
A. C. COSSOR LTD. INSTRUMENT DIVISION (Dept. HJ), HIGHBURY GROVE, LONDON, N.5.
Telephone: CANonbury 1234 (30 lines) CI.21

THE PHYSICAL SOCIETY'S EXHIBITION

The Physical Society's Exhibition at the Imperial College, London, provided also this year a most impressive display of scientific instruments. The displays included research exhibits by Government departments, universities, various research bodies and commercial firms.

A complete guide containing detailed descriptions of the exhibits may be obtained from the Physical Society, 1 Lowther Gardens, London, S.W.7. In the following some interesting exhibits are briefly reviewed.

The Automatic Coil Winder & Electrical Equipment Co. Ltd., has shown a wide range of Multi-range Test Meters and various electronic instruments. The new Model 8 AvoMeter, a 20,000 ohms per volt meter with a very wide coverage of ranges which are capable in many cases of being considerably extended by external accessories, will be of particular interest to the electronic engineer. An example of a 100 range Electronic Test Meter known as the Test-Meter Type "W" was shown, this instrument in addition to its enormous coverage of ranges being capable of giving full scale deflection for 10μA at a.c. frequencies into the audio frequency band. Other items of interest were the new Heavy Duty AvoMeter, a compact 1,000 ohms per volt multi-range instrument, a 4,000 ohms per volt Universal AvoMinor, a Universal Bridge and an Electronic Test Unit capable of producing readings of very small values of inductance and capacity. A novel form of an accurate production bridge, which can be used in works dealing with the mass production of resistive components, and a Television Receiver Testing Unit capable of checking the aerial system in addition to the receiver circuitry, are some of the most recent developments of the Company.

The exhibits of **The British Thomson-Houston Company's** Research Laboratory gave an indication of the numerous activities of the Laboratory in almost every field of electrical, physical, and chemical research.

A texture or preferred orientation camera of the moving-film type, has the novel feature that the photographic record can be used directly as the equivalent of the conventional plotted "pole figure." The photograph forms a "map" of the reference sphere but instead of the usual stereographic projection, the map obtained closely resembles a Mercator's projection.

The camera is designed to study silicon-iron sheet of varying grain size and thickness using (200) reflections and molybdenum radiation.

A BTH Type BK 56 water-cooled steel envelope ignitron for power rectification was exhibited. As a power rectifier it is rated :—

Anode Voltage (forward and inverse)	20,000 V
Anode Current average (continuous)	150 A
Anode Current (instantaneous)	900 A

Control is exercised not only by the ignitor, but also by shield and control grids ; a third grid is included for distribution of voltage stress.

A group of these valves may be connected in standard circuits for power rectification or inversion. The valve may also be used as a switch to control current pulses up to peak values of over 1,500 A in special high-voltage applications.

A variable-ratio oil-filled precision capacity divider for use on voltages up to 140-kV peak. Variable ratios of 500 : 1, 250 : 1, 125 : 1 and 62 : 1 are obtained by tapping the high-voltage condenser stack—instead of switching to lower-end capacitances—the ratio therefore being independent of changes in capacitance or power factor. The divider is sealed, changes in oil volume being accommodated by metal bellows in the top terminal.

A portable, mains-energised instrument comprising a standard 100-kV, 10 pF capacitor with a diode circuit built into an extra base attachment. The diode allows the positive half-cycles to pass, and the meter integrates these half-cycles and reads the mean value—the meter-reading thus being proportional to the peak of the applied voltage. The scale is calibrated to read the r.m.s. value of a sine wave which has the same peak value as the applied voltage.

The display of **Cinema-Television Ltd.,** included the following instruments :—

R.C. Oscillator and Automatic Frequency Monitor. Frequency range 10 cps to 100 Kcps 30V r.m.s. in 600 ohms. Accuracy $\pm 0{\cdot}005\%$ $\pm 0{\cdot}1$ cps.

Square Wave and Pulse Generator. Square Waves of 1 : 1 Mark/Space Ratio at the following maximum voltages.

5V peak to peak in 100 ohms
15V peak to peak in 300 ohms
50V peak to peak in 1000 ohms.

Repetition rate continuously variable from 5 cps to 250 Kcps. Rise time 0·015 μs in 100 ohms. Pulse widths of 0·05, 0·1, 0·2 and 0·3 μs available in 100 ohms load.

Mutual and Self Inductance Bridge. L range 0·001 μH to 30 mH. R range 100 microhms to 3000 ohms. Accuracy $\pm 1\%$. Frequency 1592 cps.

Wide Range Capacitance Bridge. C range 0·002 picofarads to 100 microfarads. R range 1 ohm to 100,000 Megohms. Accuracy $\pm 1\%$. Frequency 1592 cps.

Microsecond Counter Chronometer. For time measurement in range 1 microsecond to 1 second. Accuracy $\pm 0{\cdot}005\%$ ± 1 μs and 10 μs to 10 seconds accuracy $\pm 0{\cdot}005\%$ ± 10 μs.

Adjustable Phase Correction Units. For correction of phase distortion in wide band amplifiers.

Electronic Frequency Meter. For measuring frequencies in range 0 — 150 Kcps. Accuracy $\pm 2\%$ of full scale. Input amplitude range 0·25 to 30 volt r.m.s.

CK. Dosimeter. A personal monitor giving a direct indication of radiation dose received. Calibrated from 0 — 500 milli-roentgens in 25 m.r. steps.

High Voltage Surge Testing Equipment. For performing surge tests on any suitable impedance (e.g. motor stator windings, etc.). Comparison made on oscilloscope between a test and standard winding. Voltage pulse for testing variable from 500 volts to 10 kilovolts. Peak short circuit current 75 amps.

Electronic Instruments manufactured by **A. C. Cossor Ltd.,** include the Double Beam Industrial Oscillograph Model 1049 which has been developed for use in industrial concerns and research laboratories for measuring phenomena of zero or very low frequency and to make photographic records of transients requiring a high photographic writing speed. The oscillograph incorporates the Cossor 4 in. flat-screen double-beam tube operating at 2 kV, but provision is made for operation at 4 kV when maximum spot brightness with hair-line focus is required.

The Cossor Oscillograph Camera Model 1428 provides the simplest means of recording oscillograph pictures, either by taking single shots of a stationary waveform or, alternatively, it can be used for continuous records of non-recurrent waveforms and slow transients by the moving film method. The Cossor "Tele-Check" Television Alignment Oscillator and Pattern Generator has been designed to enable service engineers to align the R.F. and I.F. circuits and to check the time-base linearity of commercial television receivers.

MEASURING MICROSCOPES

For use in Research & Industrial Laboratories

Catalogue No. 6147

Precision Reading Microscope, Cat. No. 6145, for use in two horizontal planes. range 20 cms. with micrometer head giving direct readings to 0.01 mm. over the entire traverse. The main screw employed is of large diameter, and the pitch of 2 mm. allows for quick return to zero; can also be mounted in a vertical position for use as a Table Cathetometer. Special clamps provided for fixing the object on a plate glass platform, which is mounted on the iron base.

Two-Dimensional Precision Travelling Microscope, No. 6147, geometrically constructed and designed, with longitudinal range of 20 cms. and cross traverse of 10 cms. at right angles. The main screw employed is well aged and accurately machined. Fitted with micrometer heads reading to 0.01 mm. over a rectangle having an area of 200 sq. cms. Improved Model with new type Microscope Holder and Focussing Attachment. Curved Shields or Guards are also provided for protecting the Main and Cross Traverse Screws. The object or record is mounted on a thick plate glass platform fitted into the main frame.

An additional Low Power Microscope having a magnification of 2 diameters can be supplied at extra cost for use with the above instruments.

Also Potentiometers, Resistance Bridges, Galvanometers and accessories, Audio Frequency Bridges, pH Meters and Radio Frequency Bridge, etc.

★ **OUTSTANDING FEATURES**

Smoothness and Uniform Movements

Ease of Operation

Reliable Readings

Rigid and Robust Construction

Scientific PYE *Instruments*

W. G. PYE & CO. LTD., GRANTA WORKS, NEWMARKET ROAD, CAMBRIDGE, ENGLAND

MICRO-HARDNESS TESTER

DEVELOPED BY THE GUEST, KEEN, NETTLEFOLD LABORATORIES

This new instrument is suitable for use with a standard metallurgical bench type microscope.

It is designed to give a range of loads from 1 to 200 grams with a high degree of accuracy. The associated mechanical stage is provided with micrometer adjustments which permit very accurate movement of the specimen which is necessary for some Micro-hardness investigations. Some applications of this instrument are the measurements of :—

- ★ Hardness of phases of a micro structure.
- ★ Hardness of plated surfaces.
- ★ Case hardening and nitriding.
- ★ Hardness of thin wires, foils and soft metals.
- ★ Hardness variation in cold worked specimens.

Descriptive folder, operating instructions, prices and specialised technical details from sole manufacturers:

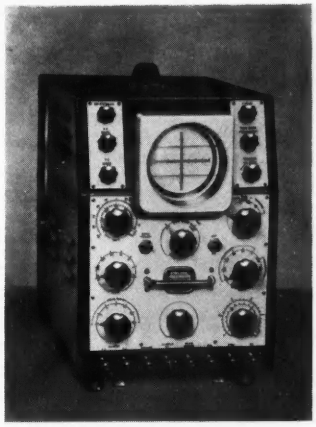
AN H.T.A. PRODUCT

HALL TELEPHONE ACCESSORIES LTD.

Precision Engineers and Instrument Makers

70 DUDDEN HILL LANE, LONDON, N.W.10.

Tel.: Willesden 5141 (8 lines). 'Grams : Halltelacc, Harles, London



The Cossor D.C. Pre-Amplifier Model 1430 is a most useful unit of laboratory equipment for the pre-amplification of minute potentials for presentation to the input of standard oscillograph amplifiers. The instrument is designed to cover the frequency range from d.c. to 30 Kcps, the response being 15% down at 30 Kcps.

The Research Laboratories of the G.E.C., have demonstrated a method by which part of the bore of a diamond wire-drawing die may be pierced with an electrical spark. The diamond is submerged in an electrolyte and a low voltage arc is used to produce a conically-shaped boring. This technique is particularly suitable for producing dies of small bore, and holes of 0·0002 in. diameter have been made.

A considerable saving of time is achieved by using the spark method in place of the more orthodox method of cutting with finely powdered diamond.

An apparatus has been designed for the quick determination of the thickness of thin metal films on insulating surfaces, for example the aluminium backing on a cathode-ray tube screen. The instrument is built around a thermionic oscillator, the frequency of which is determined partly by the presence of the metal film.

A new coaxial type crystal for use at frequencies up to 10,000 Mcps was shown. This crystal is intended for use in pretuned mixers, which are now extensively used in high-frequency radar receivers. This new valve has a markedly superior performance to the now obsolete capsule type.

Among the germanium diodes shown was a new type capable of working satisfactorily as a frequency changer up to about 1,000 Mcps. This diode has the low forward resistance characteristic which is required for use in telephone modulators. It is of the glass bead, wire-ended construction which makes for low cost in manufacture.

The design of the crystal triode has now been modified to obviate the use of a valve holder. The new design, which is hermetically sealed, is of a wire-ended form of construction so that it may be soldered directly into a circuit.

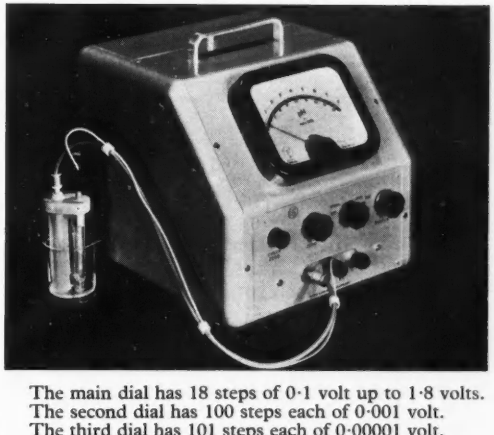
In the exhibit barium titanate resonator elements were shown to have marked advantages over certain other types of resonator elements prepared from such piezoelectric materials as quartz. One advantage is the high electromechanical coupling factor of the ceramic, which allows it to be used as a transducer capable of handling large outputs of mechanical power.

Recent developments in piezoelectric crystals for telecommunications include the growth of sizeable quartz crystals by a hydrothermal process and an impedance measuring equipment for assessing the performance of oscillator crystals at frequencies in the region of 50 Mcps. A demonstration of the electro-optical effect in crystals was given. Much of this work was done under the auspices of the Ministry of Supply.

An oscillator which was developed under the auspices of the Ministry of Supply, covers the frequency range 30 to 140 Mcps approximately, and the frequency is controlled by an applied voltage. The amplitude of oscillation remains substantially constant over most of the range and the " control voltage/frequency characteristic " is fairly linear. Any part of the band may be frequency swept at a repetition rate up to 5 Kcps by the application of a saw-tooth voltage, or any other desired waveform. One of the main applications of the instrument is in the visual alignment of amplifiers.

W. G. Pye & Co. Ltd., featured the Pye Direct Reading pH Meter, an entirely new instrument of modern design for use in industrial and research laboratories. This mains operated portable instrument, shown in our illustration, embraces a number of features not hitherto found in one unit. These include :— low zero drift, not more than $\pm$0·02 pH during a day ; stabilised sensitivity ; automatic temperature compensation ; high sensitivity, 100 micro-amps/pH ; provision for operating additional external meters ; completely protected glass electrode ; glass and reference electrodes combined in a single dip-type unit ; electrodes and all accessories self-contained.

A Precision Vernier Potentiometer shown is designed for operation from a 4-volt battery ; coarse and fine rheostats are provided for current adjustment. Three potential dials give a total range of minus 0·00001 volt to 1·901 volts.



The main dial has 18 steps of 0·1 volt up to 1·8 volts.
The second dial has 100 steps each of 0·001 volt.
The third dial has 101 steps each of 0·00001 volt.

A range multiplier switch connects a shunt across the potentiometer so that 1/10th of the main current flows through it ; at the same time a series resistor is inserted so that the total resistance remains unaltered.

The Pye Audio Frequency Oscillator embodies an entirely new type of resistance capacitance oscillator circuit, in which the frequency determining elements have been carefully chosen to ensure stability of calibration. The oscillator incorporates a control circuit which maintains the output substantially constant for all frequencies. The output circuit is resistive to maintain a level frequency response over the wide range of the instrument. A special circuit is used to ensure freedom of output variation with fluctuating mains input voltages.

The instrument has individually calibrated scales, accuracy of calibration is $\pm$1 cps below 100 cps, $\pm$1% above 100 cps. Total scale length is 20 in. approx.

Search Party...

It does not call for much investigation to appreciate the finer points of "Electro Dynamic" equipment. Here for example is featured a Variable Speed A.C. Commutator Motor possessing the following features in design and performance: fixed brush position, no slip rings, continuously variable speed.

It is worth investigation and we shall be happy to supply detailed specification.

It should be borne in mind that if this or any other "Electro Dynamic" unit does not adequately meet your requirements, we will design special equipment to do so.

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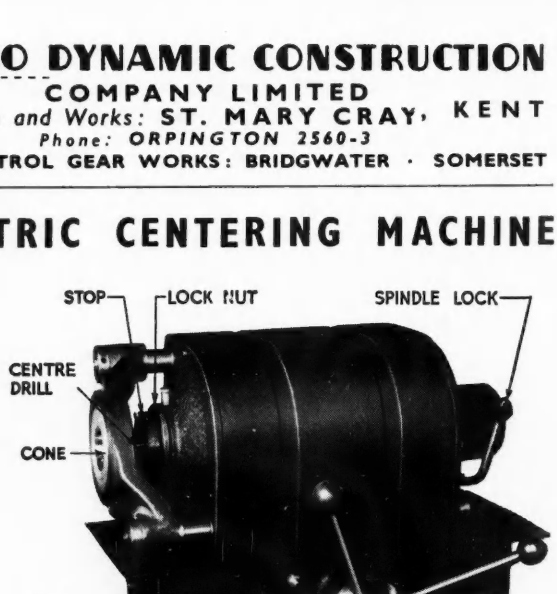
M.R.E.

CONCENTRIC CENTERING MACHINE

This illustration shows the head of the M.R.E. Centering machine with motorised head. One stroke of the tailstock centralises the workpiece in the cones and centres both ends. Production rates of up to 500 per hour can be obtained within the limits of .001" concentricity.
This machine is supplied with single or double heads as bench or pedestal model.
We make special purpose Centering, Facing and Chamfering Machines of various types to suit customer's requirements. Enquiries are invited.



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NEWS OF THE MONTH

PERSONAL

Mr. Robert W. Asquith, M.I.P.E., has been elected chairman of William Asquith Ltd., Halifax, in succession to **Mr. Lewis Rhodes** who has retired, but will continue to serve as a director of the Company. **Mr. J. D. H. Horobin,** secretary, has been elected to the Board.

Mr. H. R. Backhouse has been appointed chairman and managing director, and **Mr. H. B. Cuffin** has been appointed a director of Mellor Bromley & Co., Ltd., Leicester.

Engineer Vice-Admiral Sir Harold Brown, G.B.E., K.C.B., has accepted the position of honorary President of the Engineering, Marine and Welding Exhibition, which is to open at Olympia, London, on August 30th.

Mr. C. B. Brown, M.I.C.E., M.I.Struct.E., and **Dr. T. P. O'Sullivan, B.Sc.(Lond.), A.M.I.C.E.,** have joined in partnership as consulting engineers under the name of Brown, O'Sullivan & Partners, 16 Gloucester Place, London, W.1.

Mr. D. P. Carr has been appointed manager of the truckwork department of Edgar Allen & Co., Ltd., Sheffield.

Mr. R. E. Dymond has been appointed technical director of Electropower Gears Ltd., Kingsbury Works, Kingsbury Road, London, N.W.9.

Mr. B. Jubb, B.Sc.(Eng.), A.M.I.Mech.E., A.M.I.E.E., has been appointed sales manager of the instrument and meter division of Crompton Parkinson Ltd.

Mr. George Kelway has been appointed Birmingham area manager of A. C. Wickman Ltd., Coventry, in succession to **Mr. C. R. Perks,** who has been appointed manager of the Company's new factory at Mentone, Australia.

Mr. E. J. Lowe, local director and works manager, and **Mr. E. Wilson Hague,** local director and general sales manager, of Thos. Firth & John Brown Ltd., Sheffield, have been elected to the Board of Directors of the Company.

Mr. James E. MacLaren, managing director of the B.S.A. Tools Group of Companies, has been elected a director of the Birmingham Small Arms Co. Ltd.

Mr. G. R. Morgan, A.M.I.E.E., and **Mr. E. D. Holdup, A.M.I.Mech.E., A.M.I.E.E.,** of the South-Eastern Division of the British Electricity Authority, have been appointed by the Hydro-Electric Power Commission of Ontario, Canada, to take charge of the administration of the Commission's steam plants, and to become superintendent of the new J. Clark Keith power station at Ontario, respectively.

Mr. C. H. Noton, general sales manager of Fibreglass Ltd., Ravenhead, St. Helens, Lancashire, has been elected a director of the Company.

Mr. E. G. Plucknett, commercial director, has been appointed managing director of the Simplex Electric Co., Ltd. **Mr. A. G. Jones,** works director, has been appointed joint general manager of the Company.

Mr. W. E. A. Redfearn and **Mr. C. Muirhead,** special directors of the English Steel Corporation Ltd., **Mr. C. E. Holmstrom,** managing director of Firth-Vickers Stainless Steels Ltd., and **Dr. C. Sykes, F.R.S.,** deputy managing director of Thos. Firth & John Brown Ltd., have been appointed to the Steel (Rearmament) Advisory Panel, set up by the Ministry of Supply and of which **Mr. E. W. Senior** is chairman.

Mr. V. A. M. Robertson, C.B.E., M.C., M.I.C.E., M.I.Mech. E., M.I.E.E., who has retired from his position of Chief Civil Engineer, British Railways, Southern Region, has joined the firm of Sir William Halcrow & Partners, consulting engineers, Alliance House, Caxton Street, London, S.W.1.

Dr. E. C. Rollason has been appointed Professor of Metallurgy at Liverpool University and will relinquish his present position as director and research manager of Murex Welding Processes Ltd.

Mr. G. Sewell, A.M.I.Mech.E., chief mechanical engineer of Hopkinsons Ltd., Huddersfield, has been elected a director of the Company.

Mr. P. J. de Steiger, M.I.Mech.E., has been appointed technical manager of Silentbloc (Australia) Pty. Ltd., Doonside Street, Richmond E.1., Victoria, Australia.

Mr. C. M. Vignoles, has been appointed managing director of Shell-Mex and B.P. Ltd., in succession to **Mr. C. M. Merrick,** who has retired.

BUSINESS NOTES

Trinity Designs and Methods Ltd., has been formed as a company of technical consultants, tool designers and methods engineers, at Grosvenor Gardens House, London, S.W.1.

Colton Electrical Equipment Co. Ltd., has moved to Cranham Hall Works, Moor Lane, Cranham, Upminster, Essex. Tel.: Upminster 4454.

The New Insulation Co. Ltd., has changed the name of the Company as from the 1st April to Permali Limited. No change of personnel or break of continuity has taken place.

Clarkson (Engineers) Ltd., has started the building of an extension to its works in King Edward Road, Nuneaton.

Ductube Co. Ltd., announces that its address is now Regent House, 235-241 Regent Street, London, W.1. Tel.: REGent 2592.

G. E. Simm (Machinery) Ltd., East Parade, Sheffield 1, has been appointed sole sales representative for the Holset range of couplings, gears and torsional vibration dampers, manufactured by W. C. Holmes & Co. Ltd., Huddersfield.

Brookhirst Switchgear Limited announce that Mr. A. B. Hitch, A.M.I.Mech.E., has been appointed to the staff of Brookhirst-Igranic (S.A.) Pty., Ltd., the newly-formed Company which will promote the interests of Brookhirst Switchgear Ltd., and the Igranic Electric Co., Ltd., in South Africa.

Lincoln Cinema. A well-equipped cinema can be found in the Lincoln Electric Co. Ltd. establishment at Welwyn Garden City. Planned as part of the Lincoln training scheme for welders—this cinema seats over 20 student welders and is able to show, through its Bell & Howell-Gaumont 16-mm sound projector, a series of Lincoln films, mostly in technicolour, covering arc welding fabrication almost from start to finish.

This type of cinema is also useful as a lecture room where students assemble for discussions on arc welding subjects given by welding instructors. Lincoln arc welding equipment and the examples of welding fabrications are always at hand for demonstration. A stillograph which is electrically operated, revolves 11 photographs of various welded subjects and is also very helpful to the student welder.

The Lincoln Electric Co. Ltd., will gladly lend any of the following films for showing: The Magic Wand of Industry; Prevention and Control of Distortion; Design for Arc Welded Structures; Designing Machinery for Arc Welding; and Welding Comes to the Farm.

The Fourth Canadian International Trade Fair, which will take place in Toronto, Canada, from May 28th to June 8th, 1951, will be substantially bigger this year than ever before. So far twenty countries have applied for space; it appears likely that space booked will greatly exceed that occupied in the 1950 Fair.

Courtesy of Mather & Platt Ltd.

A 32-page booklet covering this and many other applications of the process will be sent on written request to responsible enquirers.

These impeller shafts (dia. about 6 in.) for large centrifugal pumps have been given ·008/·010 in. on radius hard chromium deposit by the Brailey Process. They will resist wear, abrasion and corrosion in a manner far superior to unprotected shafts.

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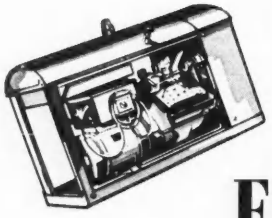

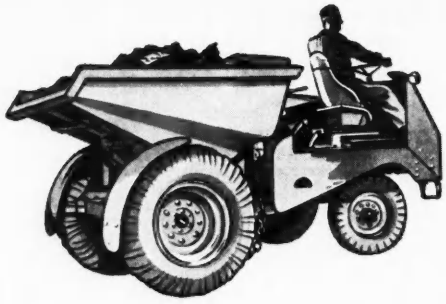

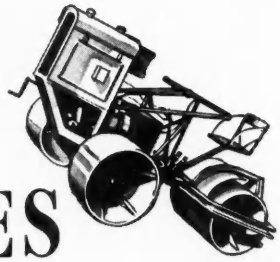

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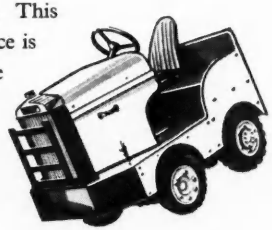

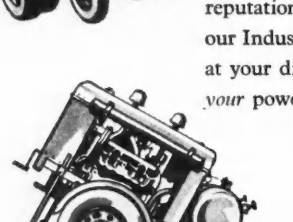

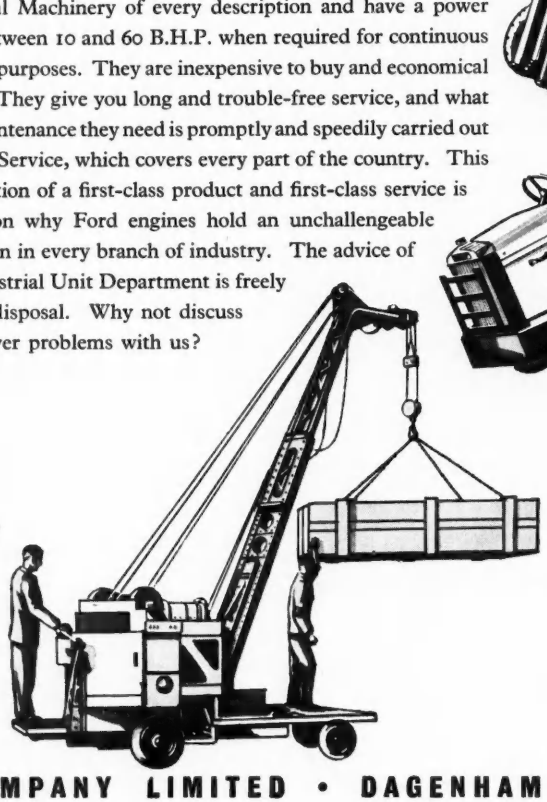

FORD MOTOR COMPANY LIMITED • DAGENHAM • ESSEX

The addition of the newly remodelled Industry Building, which is one of the four most modern exhibition halls on the continent, adds about 50,000 square feet of exhibit space to the Fair.

The Marine and Aviation Equipment section promises to be one of the most interesting features of the Fair. It will incorporate new important developments in this field from the United Kingdom, Canada, U.S.A. and Finland.

The Scientific Instrument Manufacturers' Association of Great Britain have reserved a large space in this section to show the products of their member-firms, thus following up the successes they achieved with their exhibit in the 1950 Fair.

With the introduction of the newly remodelled Industry Building to the 1951 Fair the machinery section will be bigger than ever before. The British Machine Tool Group have booked over 30,000 square feet of space, following up the successes achieved with their participation last year. In addition, several other British trade associations have taken blocks of space to exhibit a wide range of machine tools, mechanical handling equipment, printing machinery, etc. These, coupled with numerous applications from individual companies indicates that British participation in the industrial equipment sections of the Fair will be very strong. Canada and Switzerland will also have a number of interesting exhibits in the industrial sections.

A new radar device, now fully developed, shows the controller a complete screen-plan of all surface traffic on his aerodrome. Moving objects—planes, cars and pedestrians—show up as moving dots of light.

This new equipment, known as ASMI (Air Surface Movement Indicator) helps the controller to direct aircraft when visibility is down as low as a few hundred yards and a great part of the runway and taxi-track are out of sight. By using ASMI, the controller can see at a glance not only aircraft and car movements on the runway but also any obstruction in their way.

It produces its picture by an ordinary radar-scanner on a dial screen, which is so sensitive that runway lighting is reflected quite clearly and traffic can be seen moving down roads alongside the airfield. During a recent test at London Airport, controllers were able to follow a car and a small " dot " (the driver) which got out and walked round it. Aircraft taking-off down the runways move slowly forward in a series of ½ inch " jerks " each time the scanner sweeps round the screen.

The ASMI equipment, produced by Cossor Radar Ltd., is a simple installation which can be mounted in a mobile van or in a control-tower. It consists of a vertical rack about the size of a filing cabinet, the display screen and the power supply. Outside the building or vehicle is the 12-ft outdoor scanner which rotates slowly about once every two seconds. The ASMI can be worked quite easily by a non-technical operator.

The State Electricity Commission of Victoria, Australia, has just placed on order with Messrs. Boving & Co., Ltd., London, for Eildon Power Station, worth £A1,250,000 and covering two vertical Francis water-turbines each rated 82,000 hp, to drive alternators being supplied by The British Thomson-Houston Co., Ltd., Rugby. Each alternator will be rated 66,667 kVA, 11,000 volts, 3-phase, 50-cycles, 150 rpm.

The turbines are believed to have the greatest output and the alternators to be physically the largest ever ordered in Britain. The overall diameter of the alternators will be about 40 feet, and each will weigh approximately 500 tons.

WING SHAPES OF THE FUTURE

Aircraft with delta-wing shapes now being designed in British factories are setting a pattern for the high-altitude jets, rockets, and guided missiles of the future.

Three delta aircraft are already being test-flown over a wide range of speeds and smaller-scale models are being examined in wind-tunnels and structure test-rigs. Research pilots who have flown these jet-propelled types are now convinced that there are no aerodynamic difficulties in the design.

The deltas which eventually go into production may be even more radical in design than those now flying. With sharply swept-back leading edges, they may be pure " flying-wings " in which the tail-plane is eliminated because of the drag-effect it causes in flight around the speed of sound. The fin will be a swept-back triangle.

The advantage of the " flying-wing " is that its controls, fuel tanks, armament and engines are all stowed within the profile of the wing—the lift-producing surface.

The three British deltas now flying are fitted with " elevons " (a combination of elevators and ailerons) on the wing to replace the control surfaces lost by removing the tail-plane. The latest delta, the Fairey FD1, also has a small triangular tail-plane and fixed wing-tip slots to overcome the control difficulties encountered in early test-flying.

The planes carry parachutes for emergency use during test-flights for control during critical manoeuvres and speeds. The FD1 has small wing-tip parachutes and a central drogue-type parachute at the rear. The Avro 707 has an anti-spin parachute fitted above the jet-exhaust which can be thrown out as an air-brake when landing at high speed. The third delta research prototype, the Boulton Paul P111, has an anti-spin parachute housed in a blister on the port-side of the fuselage near the fin.

The designer of the P111 has incorporated specially constructed wing and fin-tips in his aircraft: these are detachable so that the effect of " clipping " the wing and fin surfaces can be studied.

All three are fitted with a tricycle undercarriage and have wings swept-back at least 45 degrees. Wing span is about 33 ft on the Avro and Boulton Paul deltas and only 19 ft 6½ in. on the sharply swept-back Fairey machine.

Performance details of the three deltas are secret. Two, the FD1 and the Avro 707, have the Rolls-Royce Derwent jet engine and the third, the P111, has the more powerful Nene.

BRITISH INDUSTRIES FAIR, 1951

(*Continued from page* 135)

The crankshaft is 10 ft long, weighs 1½ tons, as forged, and has one end left in the " as forged " condition, the middle portion sectioned and etched to show grain-flow, and the other end machined. Although possessing all the advantages of a drop forging it would be quite outside the scope of any British drop forge.

Briefly, the advantages of a crankshaft made by this method over cranks made by hitherto conventional methods are :—

1. Continuous grain-flow is ensured through all sections of the crankshaft, giving considerably greater strength.
2. Minimum of machining necessary on crank pins and journals, and periphery of webs may be left unmachined if desired.
3. Crank throws are formed at their correct relative angles without any twisting of the crankshaft.
4. Flange may be upset, giving correct grain-flow.

The crankshaft exhibited (with 6½ in. dia. pins turned) is the only size being made by this process at the moment, but smaller sizes will be available shortly and it is intended to make cranks with pins up to 15 in. diameter eventually.

Other forgings on view include a section of a hollow-forged high pressure boiler drum taken from one end of a 23 ft. 13 ton drum, a forged steel pipe mould, 6 ins. bore, 15 ft. long, a drill stem and substitutes for oil well drilling, etc.

Drop forgings on show will include jet turbine discs and crankshafts for aeroplanes and commercial vehicles.

Another interesting exhibit will be a range of Automatic Couplers for Railways, Mine Cars, Quarry Cars, etc., ranging from a large knuckle type coupler complete with draw gear, weighing 6 cwts, down to half-size Willison and A.S.F. types, weighing only a

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A great deal of importance is attached to Apprentice Training in all the various works of E.S.C., and attention is focussed on this by a small, but fine display of work carried out by apprentices during their training.

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The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box number advertisements 1s. extra. Instructions together with remittance must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

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Rapidor Filing and Sawing Machine, 400/50/3 phase.
Birlec Certain Curtain Electric Furnace Chamber, 45 in. by 18 in. by 13 in.
Horizontal Wood Morticing Machine, by Robinson with all tools, as new, 400/50/3 phase.
Reavell Centrifugal Vacuum Set (or Blower), 25 H.P. motor, 400/50/3 phase.
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Oil Tank, 1200 gallons capacity.
Boiler, suitable oil storage, approx. 5000 gallons.
Large Cupola Blower with 45 H.P. motor, 200/50/2.
Battery of Six Core Drying Cabinets, in excellent condition.
Heavy-Duty Winch, by Wilkes, 20 H.P. motor.
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having sold the premises, are instructed to offer for sale by tender as a whole or in convenient lots to suit purchaser.

The goods will be on view on **TUESDAY and WEDNESDAY 8th and 9th MAY, 1951.**

Catalogues and Forms of Tender may be obtained from the offices of the AUCTIONEERS, 9 George Street West, Luton. Tel.: 3508/9 and branches.

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